RTO-MP-096
AC/323(SAS-036)TP/27

RTO-MP-096

NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

BP 25, 7 RUE ANCELLE, F-92201 NEUILLY-SUR-SEINE CEDEX, FRANCE

RTO MEETING PROCEEDINGS 96

Cost Structure and Life Cycle Cost (LCC) for Military Systems

(Structures de coûts et coûts globaux de possession (LCC) pour systèmes militaires)

Papers presented at the RTO Studies, Analysis and Simulation Panel (SAS) Symposium held in Paris, France, 24-25 October 2001.

Published June 2003

Distribution and Availability on Back Cover

This page has been deliberately left blank

Page intentionnellement blanche

RTO-MP-096
AC/323(SAS-036)TP/27

NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

BP 25, 7 RUE ANCELLE, F-92201 NEUILLY-SUR-SEINE CEDEX, FRANCE

RTO MEETING PROCEEDINGS 96

Cost Structure and Life Cycle Cost (LCC) for Military Systems

(Structures de coûts et coûts globaux de possession (LCC) pour systèmes militaires)

Papers presented at the RTO Studies, Analysis and Simulation Panel (SAS) Symposium held in Paris, France, 24-25 October 2001.

The Research and Technology Organisation (RTO) of NATO

RTO is the single focus in NATO for Defence Research and Technology activities. Its mission is to conduct and promote cooperative research and information exchange. The objective is to support the development and effective use of national defence research and technology and to meet the military needs of the Alliance, to maintain a technological lead, and to provide advice to NATO and national decision makers. The RTO performs its mission with the support of an extensive network of national experts. It also ensures effective coordination with other NATO bodies involved in R&T activities.

RTO reports both to the Military Committee of NATO and to the Conference of National Armament Directors. It comprises a Research and Technology Board (RTB) as the highest level of national representation and the Research and Technology Agency (RTA), a dedicated staff with its headquarters in Neuilly, near Paris, France. In order to facilitate contacts with the military users and other NATO activities, a small part of the RTA staff is located in NATO Headquarters in Brussels. The Brussels staff also coordinates RTO's cooperation with nations in Middle and Eastern Europe, to which RTO attaches particular importance especially as working together in the field of research is one of the more promising areas of initial cooperation.

The total spectrum of R&T activities is covered by the following 7 bodies:

- AVT Applied Vehicle Technology Panel
- HFM Human Factors and Medicine Panel
- IST Information Systems Technology Panel
- NMSG NATO Modelling and Simulation Group
- SAS Studies, Analysis and Simulation Panel
- SCI Systems Concepts and Integration Panel
- SET Sensors and Electronics Technology Panel

These bodies are made up of national representatives as well as generally recognised 'world class' scientists. They also provide a communication link to military users and other NATO bodies. RTO's scientific and technological work is carried out by Technical Teams, created for specific activities and with a specific duration. Such Technical Teams can organise workshops, symposia, field trials, lecture series and training courses. An important function of these Technical Teams is to ensure the continuity of the expert networks.

RTO builds upon earlier cooperation in defence research and technology as set-up under the Advisory Group for Aerospace Research and Development (AGARD) and the Defence Research Group (DRG). AGARD and the DRG share common roots in that they were both established at the initiative of Dr Theodore von Kármán, a leading aerospace scientist, who early on recognised the importance of scientific support for the Allied Armed Forces. RTO is capitalising on these common roots in order to provide the Alliance and the NATO nations with a strong scientific and technological basis that will guarantee a solid base for the future.

The content of this publication has been reproduced
directly from material supplied by RTO or the authors.

Published June 2003

ISBN 92-837-0034-1

ST JOSEPH
OTTAWA/HULL

Printed by St. Joseph Print Group Inc.
(A St. Joseph Corporation Company)
1165 Kenaston Street, Ottawa, Ontario, Canada K1G 6S1

Cost Structure and Life Cycle Cost (LCC) for Military Systems

(RTO MP-096 / SAS-036)

Executive Summary

Costs have long since become a major issue in military systems analysis. Attention is not limited to the acquisition costs alone, but encompasses all costs involved in the use and disposal of systems. Concepts such as Life Cycle Cost (LCC), Whole Life Cost (WLC), Cost of Ownership (COO) or Total Ownership Cost (TOC) are more and more frequent in any document dealing with system analysis. Most nations have developed and use their own definitions, methods and tools, which may cause problems when it comes to working together at multinational level. This is why a study has been undertaken under the auspices of NATO to harmonise the most important aspects of LCC. The study carried out by the technical team SAS-028 covered three concurrent areas: the cost breakdown structure that defines and organises all cost elements to be considered, the boundaries of those cost elements defined by LCC, TOC, COO and WLC and the uses of those concepts (economic or financial analysis, optimisation, etc.) by decision makers.

The symposium focused on these and other objectives for the introduction of Life Cycle Management (LCM) and the need for an action plan for the near, medium and long term to be carried out under the guidance of a higher NATO authority. The need for accurate objective based Cost estimation was clearly identified as a requirement to meet the future estimation and forecasting challenges, and the utilisation of both commercial and non-commercial practices and the consideration of total life costing was considered essential if the life cycle process was to be shortened. Clear differences were identified between these two (commercial, defence) paradigms and various successful costing models were presented. These models, whether developed independently or jointly, may differ in structure but clearly show similarities in some of the identified cost drivers. Further, they clearly demonstrate that there is a great deal of expertise and experience being gained throughout the NATO community, and their presentation at a single forum give nations the opportunity to present their own practices and experiences, thus fostering exchange of information among the NATO and partner communities, and to strengthen LCC studies in multinational projects.

Structures de coûts et coûts globaux de possession (LCC) pour systèmes militaires

(RTO MP-096 / SAS-036)

Synthèse

Les coûts sont depuis longtemps l'un des principaux enjeux de l'analyse des systèmes militaires. La question n'est pas limitée aux seuls coûts d'acquisition mais englobe l'ensemble des coûts associés à l'exploitation et à la mise au rebut des systèmes. Des concepts tels que le coût du cycle de vie (LCC), le coût sur toute la durée de vie (WLC), le coût de possession (COO) et le coût global de possession (TOC) sont cités de plus en plus fréquemment dans les documents traitant de l'analyse des systèmes. La plupart des pays ont développé leurs propres définitions, méthodes et outils, ce qui risque de poser des problèmes lorsqu'il s'agira de travailler en commun au niveau international. Une étude a donc été lancée, sous l'égide de l'OTAN, afin d'harmoniser les aspects les plus importants du LCC. L'étude réalisée par l'équipe technique SAS-028 a porté sur trois domaines concurrents, à savoir : La structure de ventilation de coûts qui définit et constitue le cadre de l'ensemble des éléments de coût à prendre en considération, les limites de ces éléments de coût telles que définies par LCC, TOC, COO et WLC, ainsi que la mise en œuvre de ces concepts (analyses économiques et financières, optimisation, etc..) par les décideurs.

Le symposium a privilégié ces questions, ainsi que la mise en application de la gestion du cycle de vie (LCM) et la nécessité de prévoir un plan d'action à court, à moyen et à long terme, à exécuter sous la direction des autorités supérieures de l'OTAN. Les participants ont clairement identifié le besoin de disposer d'une méthode d'estimation de coûts basée sur les objectifs, afin de pouvoir relever les futurs défis dans les domaines de l'estimation et la prévision De même, il a été considéré primordial d'adopter des pratiques commerciales et non commerciales et de prendre en compte les coûts du cycle de vie global pour écourter le processus du cycle de vie. Des différences notables entre ces deux paradigmes (commercial, défense), ont été identifiées et différents modèles d'évaluation de coûts réussis ont été présentés. Ces modèles, développés soit indépendamment, soit conjointement, même s'ils sont structurés différemment, montrent des similitudes marquées du point de vue de certains générateurs de coûts bien définis. En outre, ils fournissent la preuve de l'ampleur de l'expérience et des compétences qui sont en train d'être acquises par les pays de l'OTAN. Leur présentation dans un forum unique donne aux pays membres l'occasion de présenter leurs propres pratiques et expériences, favorisant ainsi un échange d'informations entre les pays de l'OTAN et ceux du Partenariat pour la Paix. De tels échanges serviront à confirmer l'intérêt des études LCC dans le contexte de projets multinationaux.

Click inside the blue boxes or on the titles to view the corresponding section

Contents

	Page
Executive Summary	**iii**
Synthèse	**iv**
Theme/Thème	**vii**

	Reference
Generic Cost Breakdown Structure by G. Seguin	**1**
Life Cycle Cost, Total Ownership Cost and Whole Life Cost by M.C. Smit	**2**
The Use of Life Cycle Cost and Nature of Decisions by A. Özkil	**3**
Life Cycle Management in NATO by E. Fajardo, R. Herreman, G. Glenister, S. Di Cicco and C. Bouman	**4**
Life Cycle Costing in a Commercial Style Accounting Regime as it Impacts U.K. MoD by J. Burridge	**5**
Cost Estimating and Forecasting in the New Era of Smart Procurement by B.J. Hilton	**6**
Innovations and Improvements in Cost Information Management by D.M. Robinson	**7**
Visibility and Management of Operating and Support Costs (VAMOSC) Management Information System by L.P. Cheshire	**8**
OSCAM – Simulating Operation and Support Costs Using System Dynamics by J. Burridge and J. Coyle	**9**
Life Cycle Cost Simulation in Defence Planning by J. Komarek	**10**
L'élaboration de modèles spécifiques à la DGA **(Specific model development for the French procurement)** by A. Capy and C. Pereira	**11**
A Software Support Cost Model for Military Systems by J. Gibbs	**12**
Life Cycle Cost Procurement Techniques by A. Özkil	**13**
Expérience navale française nationale et en coopération concernant le LCC et le Cost Structuring **(Naval Experience Concerning LCC & Cost Structuring)** by P. Garnier	**14**

LCC Analysis for the Replacement of the Dutch F-16 15
by R.C.T. de Haas, M.C. Smit and K.I.M. de Zeeuw

Application de modèles de coûts à un système de transmission 16
(Cost Models applied to a transmission system)
by M.-P. Pez, E. Arbaretier and S. Pierron

Monolith Composite Structures – Trend for Creation Low Life Cycle Cost Airframes 17
by N.W. Pkhaladze and G.O. Rusiashvili

The NATO Research & Technology Organization (RTO) – Overview 18
by C. Mounier

Strategic Cost Model to Support High Level Operational Analysis 19
by D. Barradale

Realistic Cost Estimates for Acquisition Programs: CAIG Perspectives 20
by R. Burke

Overview of the Symposium Topics 21
by G. Seguin

Discours de clôture 22
(Closing remarks)
by B. Besson

Theme

Costs have long since become a major issue in military systems analysis. Attention is not limited to the acquisition costs alone, but encompasses all costs involved in the use and disposal of systems. Concepts such as Life Cycle Cost (LCC), Whole Life Cost (WLC), Cost of Ownership (COO) or Total Ownership Cost (TOC) are more and more frequent in any document dealing with system analysis.

Most nations have developed and use their own definitions, rnethods and tools, which may cause problerns when it cornes to working together at multinational level. This is why a study has been undertaken under the auspices of NATO to harmonise the most important aspects of LCC.

The study carried out by the technical team SAS-028 covered three concurrent areas: the cost breakdown structure that defines and organises all cost elements to be considered, the boundaries of those cost elements defined by LCC, TOC, COO and WLC and the uses of those concepts (economic or financial analysis, optimisation, etc.) by decision rnakers.

The first objective of the Symposium is to present the findings of SAS-028 to NATO and Partnership for Peace (PfP) nations. The second objective is to give nations the opportunity to present their own practices and experiences, thus fostering exchange of information among countries, and to strengthen LCC studies in multinational projects.

Thème

La question des coûts est devenue, depuis longtemps, l'un des éléments majeurs dans l'analyse des systèmes militaires. L'attention ne se porte pas seulement sur les coûts d'acquisition, mais aussi sur l'ensemble des coûts associés à l'utilisation et à l'élimination des systèmes. On voit de plus en plus souvent apparaître, dans tous les documents en anglais traitant de l'analyse des systèmes, des concepts tels que le Life Cycle Cost (LCC), le Whole Life Cost (WLC), le Cost of Ownership (COO) ou le Total Ownership Cost (TOC), auxquels correspondent à peu près, en français, les concepts de coût global de possession (CGP), de calcul des coûts sur l'ensemble de la durée de vie ou de coût du cycle de vie.

La plupart des pays ont élaboré et utilisent leurs propres définitions, méthodes et outils, ce qui peut entraîner des problèmes lorsqu'il s'agit de mener des travaux en commun au niveau international. C'est pourquoi une étude a été entreprise, sous l'égide de l'OTAN, en vue d'harmoniser les aspects essentiels du CGP.

L'étude, réalisée par l'équipe technique SAS-028, couvrait trois domaines parallèles : structure de ventilation des coûts, définissant et organisant tous les éléments de coût à prendre en compte; limites de ces éléments de coût définies par les concepts de LCC, WLC, COO et TOC; et utilisations de ces concepts (analyse économique ou financière, optimisation, etc.) par les décideurs.

L'objectif principal du Symposium sera de présenter les conclusions du SAS-028 aux pays membres de l'OTAN et aux pays membres du Partenariat pour la paix (PPP). Le second objectif sera à la fois de donner aux pays l'occasion de présenter leurs propres pratiques et leur expérience, favorisant ainsi les échanges d'informations entre eux, et de développer les études sur le CGP dans les projets multinationaux.

This page has been deliberately left blank

Page intentionnellement blanche

Generic Cost Breakdown Structure

Gérard Seguin
DGA/DPM/MCO/EL
26, Boulevard Victor
00460 Armées
France

In the interests of readability and understandability, it is RTO policy to publish PowerPoint presentations only when accompanied by supporting text. There are instances however, when the provision of such supporting text is not possible hence at the time of publishing, no accompanying text was available for the following PowerPoint presentation.

Click here to view PowerPoint presentation; Press Esc to exit

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

This page has been deliberately left blank

Page intentionnellement blanche

Life Cycle Cost, Total Ownership Cost and Whole Life Cost

M.C. Smit
TNO-FEL
P.O. Box 96864
2509 JG The Hague
The Netherlands

In the interests of readability and understandability, it is RTO policy to publish PowerPoint presentations only when accompanied by supporting text. There are instances however, when the provision of such supporting text is not possible hence at the time of publishing, no accompanying text was available for the following PowerPoint presentation.

Click here to view PowerPoint presentation; Press Esc to exit

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

This page has been deliberately left blank

Page intentionnellement blanche

Click here to view PowerPoint presentation; Press Esc to exit

The Use of Life Cycle Cost and Nature of Decisions

Maj. Altan Özkil (MS in OR)
Turkish General Staff Headquarters
Scientific Decision Support Center
General Analysis Team Leader
06100 Bakanlıklar, Ankara, Turkey

Introduction

The use of life cycle cost must, whatever the phase of a programme, inform the process by which managers can bid for future expenditure, manage existing budgets and make the best decisions on options presented to them. Most of the major costs determining decisions are made during the initial phases of the Defense Program Management. In this early decision period, the type of system technology procured, the basic design, the support system and the maintenance concept are determined. Decisions made in the early phases of any particular defense program freeze up to eighty percent of the potential life cycle cost of the aforementioned defense program. For this reason, it is essential that detailed and accurate assessments of anticipated costs must be made as early as possible.

The general use of life cycle cost

There are two main purposes for using life cycle cost as a decision support tool for the program managers, analysts, project and team leaders etc. One of the main purposes is to use life cycle cost in economic appraisal and the other purpose is financial appraisal.

- Economic Appraisals are generally undertaken by organizations and Government bodies with an eye to the 'well being' of that organization or country as a whole. As such they address opportunity costs (alternative use of assets or resources) but usually not simple transfer payments such as national taxes that 'move around' the economy. Economic analysis may be simply summarized as

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

addressing the costs and benefits of options to the national coffers and is not, necessarily, therefore concerned about precisely which part of the Department's budget is impacted. Any common costs not impacting the decision may be excluded to simplify, and hence reduce the costs of, the exercise.

- Financial Appraisals however include all cash flows and transfer payments and hence assess affordability. In financial appraisal, costs need to be split by budget holder, so they know their contribution, by phase to understand the significance over the life cycle and by major 'input' cost category (manpower, stocks purchased, in year expenses etc).

These two types of appraisal, although different, are not exclusive. They can make LCC a management and engineering tool with which to forecast and optimize the costs of a system. Whatever the type of use, the predictive use of LCC represents its principal interest.

LCC must be used as a benchmark against which options can be measured for 'value for money' during the acquisition process, bearing in mind that the greatest opportunities to reduce LCC usually occur during the early phases of the programme. It follows LCC is used as a decision and optimization criterion in the search of the best compromise between time, cost and performance.

The general phases in the use of LCC

Early in the project life cycle, studies need to address the capability gap, the numbers of equipment or platforms required and the technologies that can help to fill the gap at lowest cost. This requires a 'strategic' approach that can provide a capability to look at the 'big picture'. At this phase in the life cycle it is unlikely that the costs can be identified in a great deal of detail, rather an understanding of the 'big hand-falls' in terms of primary CBS elements and the uncertainty surrounding these figures is required.

Once a project team has been formed and given a user requirement, the focus turns to the performance, cost and time envelope of various options that will meet the requirement. Forecasts of costs for new equipment and platforms are needed. This requires an approach and tools/models that have a holistic view and can provide a 'what if' capability. The CBS can be developed and extended to reflect the acquired knowledge of the expected system characteristics.

When the preferred generic option (e.g. develop a new vehicle) is identified, industry is generally asked to compete for its supply. Assessments of these bids are based on life cycle cost analysis and need to address economic and financial treatments. Cost figures need to compliant with rules set by Governments on investment appraisal set out by central Government (usually the country's Treasury department) and at the same time provide the data by which budgets can be agreed for the long-term operation and support of the assets. At this stage the CBS should be fully developed such that all cost elements are identified.

For in-service equipment a forecast of the costs for the remaining life are required. Whilst any in-service equipment, not nearing the end of its service life is generally considered to be in the middle of the 'bathtub' in respect of reliability, major cost drivers are driven by 'change milestones' caused by events such as overhaul, deployment, updates and safety reviews. Towards the end of equipment life, ageing effects may increase support costs or reduce availability. Not all equipment goes out of service on a particular date so phasing out expenditure depends on the introduction profile of new equipment or capability. Delays to new equipment can result in extra funds being required to continue support of legacy equipment. These costs need to be addressed and budget adjustments calculated.

In summary, it is not possible or desirable to collect and analyze information at the same level of detail throughout the life cycle although there should be a common thread in terms of programme phases, main CBS groupings and resource consumption.

Economic Appraisal

Economic appraisals lead to selection of a preferred alternative for a project. After completing the cost and benefit estimates for each alternative, the individual responsible for a program or project will establish priorities and identify his or her own preferred alternatives by making comparisons of the costs and benefits of the feasible alternatives with respect to the status. The results of the comparison and a recommendation will be presented to the decision makers.

As a rule, the preferred alternative will be the alternative that provides the greatest amount of benefits in relation to its cost. In situations where it is difficult to quantify benefits and measures of effectiveness, it is important to provide as much useful information as possible so that a decision can be made as to which alternative yields the most benefits. These usually take the form of a cost benefit analysis or cost effectiveness analysis.

A cost benefit analysis is an exercise in which all of the costs and benefits of an activity are quantified and valued in monetary terms. It is therefore possible to evaluate and compare options and see if the benefits exceed the costs i.e. 'send to save'. Benefits, such as reduced loss of life, may be set against expenditure although there may be religious and political objections to this approach.

A cost effectiveness analysis compares the costs to be expended (often discounted in later years to reflect the national time preference when spending money obtained through taxation) with the effectiveness of alternate ways of meeting an objective. By combining the analysis a measure of cost effectiveness can be obtained that can be used to decide between options.

In both cases it is possible to address just the marginal cost change from the 'status quo' if the other fixed costs apply equally to all options. It is important not to assume cost savings that cannot be realistically achieved. Where alternatives have differing economic lives, the analyst must determine whether the longest or shortest life

or some other time period is to be used as a basis for comparison, and make an adjustment for unequal life.

There are a variety of quantitative methods and techniques available for comparison purposes when performing an economic appraisal. These methods and techniques provide a more definitive basis in the ranking of alternatives. Quantitative analysis of costs and benefits and the resultant ranking of alternatives can be performed by discounted and undiscounted methods and techniques. Some of these methods and techniques are as follows: Benefit cost ratio analysis, the break-even analysis, the savings investment ratio analysis, the savings investment ratio analysis, net present value, rate of return.

Financial Appraisal

The control of costs requires knowledge of current and, probable, future expenditure against assets and services. Because financial appraisal deals with budgets it is important that it is comprehensive in its coverage. Any cost breakdown structure must capture all costs.

Each nation will have their own financial control systems and these will demand different cost elements. Any CBS must therefore be as consistent as possible with each national system.

In financial appraisal it is not appropriate to employ discounting but it is important to consider all of the resources consumed in meeting an objective and any taxes that fall to a Department's budget. These will vary by country and need to be identified separately.

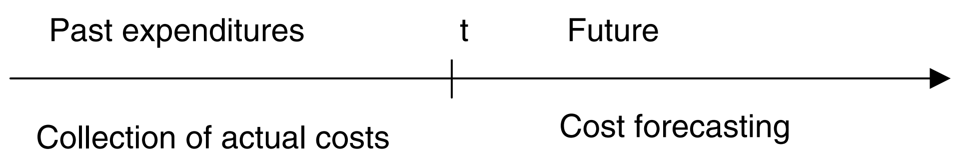
Two approaches are generally employed. Financial accounting deals with day-to-day budget control and is concerned with detailed costs. It may be less concerned with equipment costing and does not usually provide data that can be easily related to equipment's CBS. Management accounting takes the same basic data but permits day-

to-day project control and decision support. This is where an equipment CBS is most appropriate.

Time Related Evaluation Factors

At any time "t" in its life cycle, a system usually contains two categories of costs.

- Past expenditures usually referred to as "sunk costs" and firm undertakings that cannot be undone without financial loss known as "committed costs".
- Future expenditures that can be amended even if there are political or severe structural implications.



To support forecasting of LCC it is essential to have a good knowledge of actual acquisition and in-service costs. Collection of actual costs during the system life cycle helps:

- To analyze differences between forecasting and actual costs,
- To feed costs databases,
- To identify cost drivers,
- To implement management control.

Any CBS must be as consistent as possible with each national "costs collecting" system although it is recognized that this depends to a large extent on the structure, and thus commonality of systems, even within one country's financial or management systems. For the exchange of data or comparison of costs within NATO it will be necessary to understand the background to the purpose behind the use of LCC and if necessary 'translate' that information into a form that can be 'mapped' to a common CB.

The Use of LCC in Project Management

Project Initiation Phase

The project initiation phase identifies a shortfall in capability. This shortfall is detailed in some necessary documents. Upon the approval of the shortfall by the management, the project will be initiated and the project planning will be started.

Project Planning and Development Phase

People try to identify options available to meet the need, analyze these options and plan the activities for the next phases. One of the major functions performed during the Project Planning and Development Phase is a review and comparison of options to determine the single or possibly two or three most attractive solutions that could satisfy the need.

Life Cycle Costing is the method used to quantify the relative costs to acquire and operate each option. This analysis will develop the costs for each option. This could be the first estimate of Life Cycle Cost (LCC). The first estimate of LCC is based upon a comprehensive statement of requirement in mission terms and an outline of a solution. Such an estimate is strictly an indication of the total project cost and completion date.

After this preliminary evaluation, a Program Planning Proposal (PPP) is prepared. The PPP identifies resources required in broad terms and is equivalent to a pre-feasibility study. Following approval of PPP, a Project Development Study is performed. This more detailed study analyses the various options of meeting the need in more detail in areas such as: capability, life cycle costs, personnel, technology and overall impact on DND. Upon the completion of these analyses, the second estimate of LCC is derived.

The second estimate of LCC is based on the general description of the end item sought, on production/construction experience, on the market conditions or on system concept or preliminary design and analysis of its cost and schedule conducted by experienced personnel. This second estimate of LCC would be sufficient for making the

correct investment decision. This estimation is used in preparing of Program Development Proposal. Whenever management approves it, the project definition phase begins.

Project Definition Phase

This phase involves a more detailed analysis of the preferred option, or additional options if required. The option(s) is analyzed to determine the probability of meeting the project requirements in relation to cost, time and performance. As well, the next phase, Implementation, is planned in detail.

From this analysis, the third estimation of LCC is prepared. It is based upon data (relative to cost, timing and production or construction) of quality. This estimation should provide for the establishment of realistic project objectives sufficiently accurate to obtain effective project approval.

The report concerning the project definition phase and the third estimate of LCC are used to prepare Program Change Proposal. When it is approved, the project implementation phase begins. The Project Implementation Phase is the final phase of the acquisition environment.

The Use of Life Cycle Cost in Acquisition Process

The defense planning activities begin with the identification of a need and continue through to the implementation of the most effective method of meeting that need. A project is initiated in response to a need to meet some capability, which is not being met. As this process progresses from the concept phase through planning development and definition, a number of factors must be considered, including meeting the mission requirements, time, socio-economic factors and cost.

A system life cycle usually consists of four phases. These are conception, acquisition, in-service and disposal.

During the conception phase, our concern is about the magnitude of life cycle costs, the technical feasibility of the proposed maintenance concept, the potential risks involved in any specific option and for assistance in performing various trade-off analyses. There may not be a great amount of detail available on the systems, but through various data banks and LCC models, we will be able to assist in determining estimates for costs in areas such as personnel, facilities, support equipment, spare parts, publications, training and training equipment, technical data, etc.

During the acquisition stage, LCC expert evaluates the contractor's submissions to validate the LCC and R&M data and begins monitoring the support system to ensure its effectiveness.

During the in-service stage, the LCC manager continuously monitors the system's effectiveness by comparing the previously estimated values of LCC with the actual values incurred to identify trends and possible problem areas, and to determine causes and interrelated effects.

In the disposal stage, we must determine the most cost-effective and operationally effective alternative. This involves using LCC to compare options to modify, rebuild or replace the system. If the system is to be replaced, the LCMM reviews the support system elements, which may be reassigned, and the most cost-effective disposal method for the non-usable elements.

The Use of Life Cycle Cost in Defense Planning

The techniques of LCC are used to assist the project managers and various levels of decision-makers in making the most cost-effective decisions based upon data, which has been collected and analyzed in a logical and coherent manner. The data from the LCC analysis is used for;

- Long Term Defense Planning,
- Comparison of Competing Projects,
- Comparison of Logistic concepts,

- Decisions About Replacing Aging Equipment,
- Selection Between Competing Contractors.

LCC may consider non-cost related factors, which may influence decision. These factors include political decisions based on socio-economic benefits; safety related decisions, which may preclude using certain cost-saving material procedures; and legal requirements imposed upon the use or maintenance of a system.

Long Term Defense Planning

Long term defense planning, beyond ten years, requires careful analysis of all quantifiable factors which may impact the system under review, whether this is the complete defense services program or a specific project such as new ships. Most major new projects require more than five years from the start of the initial needs analysis to the actual acquisition of the system, and the system's operation and support costs must be borne by DND for between fifteen and twenty-five years. Therefore, accurate estimation of life cycle costs is a major responsibility of DPMS planners.

LCC techniques force the user to accurately define the various phases of the project. This definition requires an analysis of the work to be performed, the deliverables, and the cash flow and management requirements to control project. To determine the work to be performed, the project planners must prepare a work breakdown structure (WBS) or each phase of the project and integrate this with all related work breakdown structures. This procedure ensures that all applicable cost/work areas will be considered in the next stage of the procedure, which is estimating the costs for each work package. This WBS forms the foundation for the budgeting process. The principal cost categories should continue to be used for cost tracking over the entire life cycle of the system.

Each work package in the WBS must have an identifiable output, which can be assigned an estimated cost and a time frame for completion of that output. This relates expected costs to specific phases of a project and provides a cost profile of when project

costs are expected to occur. In summary, the use of LCC techniques in long term defense planning will:

- Define details of activities in specific phases of a project (WBS),
- Relate expected costs to specific phases of a project (Cost Allocation)
- Provide a cost profile of when costs are expected to occur (Cash Flow Projections).

Comparison of Competing Projects

The comparison of competing projects is an ongoing exercise as a number of projects attempt to obtain limited funds. The comparison of competing projects includes the determination of which option is the effective in a particular project. The philosophy concerning the application of LLC techniques is the same for every option.

LCC provides a rational, logical and supportable comparative technique for the estimation of the total cost of ownership of different options. When comparing different system options, the most cost-effective technique is to analyze and consider only those aspects of a system, which are different. The use of scarce resources to analyze factors, which will have no bearing or impact on the final decision, is not cost effective. As LCC forces the user to plan more deeply and do more analysis with hard data, the actual differences between system options will become more apparent and allow a more rational analysis to be done.

Comparison of Maintenance Concepts

The maintenance concept is the basis for all aspects of the total support system. It determines where items will be repaired, removed and stored; who will be responsible for performing specific maintenance actions; what personnel an skills will be used; and who will manage the support system and all of its components.

The maintenance concept used on any particular system has a large effect on the maintenance resources required to support the system. LCC allows a planner to

evaluate the effect of different maintenance concepts on any particular system option or analyze the effects of a particular system's support requirements on an established maintenance concept.

Some of the major factors considered in a maintenance concept are:

- The operational scenario of the system,
- Available resources such as funding, skilled personnel, etc.
- Sources of supply, both military and civilian,
- Cooperative logistic agreements proposed or in place,
- Technology of system,
- The applicability of the established maintenance concept.

LCC allows the planner to compare different maintenance concepts and determine what cost effect the concepts may have. Once again, it is most cost effective to compare only the difference between the concepts and not consider the total life cycle costs at this point in the analysis.

Replacing Aging Equipment

As equipment ages, the support of that equipment tends to become increasingly expensive. At some point in time a decision must be made to either rebuild/refit the equipment or explore alternative methods of meeting the operational requirement. This decision is necessary when it has been determined that the present system either cannot meet the operational needs or the support costs are too great to continue carrying the present system in the inventory.

Life cycle costing is the optimum method used to address the three possible options available in resolving this scenario.

- The first possibility is to examine the support costs being incurred and determine if these costs may be reduced through the use of more advanced maintenance techniques or better support planning and operation.

- The second possibility is to determine the benefits, which may be realized by performing a rebuild/refit on the system to incorporate subsystems, which will reduce the maintenance and support system demands.
- The third and final possibility is to assess the impact on support system resource demands, which may result from replacing the old system with a new system, designed to reduce the support requirements needed to maintain the new system.

In essence, the life cycle costing approach provides the planner or life cycle manager with the tools required to make sound, rational decisions to determine which of the possible alternatives under consideration is the most cost effective.

Selection Between Contractors

The cost of operating and supporting a system is, in most cases, significantly greater than the cost of acquiring it. For this reason, the post-acquisition costs have become an increasingly important component of the evaluation of potential contractors' proposals.

Contractors are being required to provide data on expected support costs either as estimate figures or as contractually guaranteed cost figures. The evaluator, planner or manager must determine when it is to the their advantage to require a contractor to provide either estimated data or contractually guaranteed data. Before a data requirement is imposed on the contractor, the manager must determine the specific cost data required, the amount of detail necessary and the degree of accuracy desired.

The contractor incurs a cost increase when data must be contractually guaranteed. This cost is directly related to the level of risk inherit to the provision of such data. If the data is guaranteed and the guarantee can be enforced, then the manager has relatively little analysis to do to confirm its accuracy; however, if the data is merely estimated, the manager must then have the means of evaluating the data and determining its accuracy in their needs.

When the data is to be used for the evaluation of proposals submitted by competing contractors, the manager's needs may only include data concerning the differences between the various alternatives and not the absolute costs for each alternative.

As a result, it is obvious that the techniques of life cycle costing can be used by the Life Cycle Manager as prime method for carrying out planning and management responsibilities.

Click here to view PowerPoint presentation; Press Esc to exit

Life Cycle Management in NATO

Emilio Fajardo, Robert Herreman
Graeme Glenister, Sergio Di Cicco
Cornelis Bouman
NATO CALS Office
NATO HQ
Boulevard Léopold III
1110 Brussels, Belgium

Summary

Traditionally, NATO acquisition and logistics have operated through a series of relatively independent processes and organisations. The November 99 CNAD meeting (Conference of National Armaments Directors) confirmed a recommendation from the NATO Armament Review (NAR) to create a Life Cycle Working Group.

This working group has adopted Life Cycle Management (LCM) principles and has accepted the following mission statement for its work:
"To propose guidance in the area of Life Cycle Management to CNAD by providing:
A study of the basic elements (principles and definitions) needed to define a NATO-policy on LCM and a framework (high level process model) and a proposal to move forward."

This paper gives an overview of the contents of the report, which among others mentions the objectives for introducing LCM in NATO.

Furthermore a definition for LCM is given and reasons are given why LCM might provide us with the necessary changes in our organisations to meet the demands of our war fighters and other stakeholders.

It is clear that managing the total life cycle in organisations means ***the integration of the acquisition and logistic processes***. However implementing LCM in an organisation is not done without the necessary preparation. A number of key enablers need to be in place before any implementation can even start.

An important enabler is ***"a unified business process methodology"*** which gives us the tool to develop a common framework to describe the life cycle of a system by a complete set of well-defined processes and associated terminology. Based on this a life cycle management model is presented.

Although the work that has been done by the Life Cycle Working Group is of great importance it cannot stop here. In order to take LCM forward in NATO the Life Cycle Working Group recommends an action plan for the near, the medium and the long term to be carried out under the leadership of a high NATO authority.

In order to make the transformation to LCM a success for NATO the Life Cycle Working Group has recommended to ***CNAD*** to investigate the broadest possible participation of other organisations in NATO. Furthermore a high level Committee under CNAD should investigate in close co-ordination with SNLC and NC^3Board how these actions for the near, medium and long term can effectively be implemented in NATO.

The NADREPs (National Armaments Directors Representatives) on behalf of the CNAD have approved at their 12th March 2001 meeting the Life-Cycle WG report and the NCMB was tasked to continue this important work and to act upon the given recommendations.

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

Introduction

Traditionally, NATO acquisition and logistics have operated through a series of relatively independent processes and organisations. The delivery of materiel and services have focused on each element of the process (e.g., supply, maintenance, transportation, procurement, and finance), each operating independently but interfacing at appropriate points along the delivery path. At the same time, diverse organisations were responsible for stand-alone portions of the logistics process. This approach has resulted in sub-optimal efficiency of the total process, some duplication of effort, and management and technical solutions oriented to individual segments of the process. A focus on customer requirements and satisfaction has been absent or, at best, dependent on each logistics sub-process or organisation's perception of customer needs.

The November 99 CNAD meeting (Conference of National Armaments Directors) confirmed a recommendation from the NATO Armament Review (NAR) to create a Life Cycle Working Group. From NAR report AC/259-D/1792 dated 22 November 1999, we quote:
"… the concept addressed by the NATO Armaments Review covers the optimisation of all aspects of a defence system's performance over its whole life cycle, including those activities relating to in-service support. In order to further elaborate this concept it would be desirable to develop both a policy and a model. This might then suggest that the CNAD's Phased Armaments Programming System (PAPS) could, if appropriate, take into account these life cycle support considerations. A Life Cycle Working Group will develop these products and provide its report to the autumn 2000 CNAD meeting."

This working group identified that through adoption of Life Cycle Management (LCM) principles; NATO can develop a more integrated, efficient, and customer-oriented logistics process.

Based on this, the Life Cycle Working Group accepted that the following mission statement for its work:
"To propose guidance in the area of Life Cycle Management to CNAD by providing:
A study of the basic elements (principles and definitions) needed to define a NATO-policy on LCM and a framework (high level process model) and a proposal to move forward."

Is there a need for improvement?

The preliminary findings of the Life Cycle Working Group identified that Projects seldom meet the requirements of all stakeholders. The main reasons for this are deep-seated in our organisational culture which could be summarised in the following three main categories:

- *Poor management*: Some of the shortcomings often encountered in our defence organisations are insufficient resources at the early procurement stages of projects. At the same time they are subject to cumbersome approval processes, rigid procedures, ineffective incentives available to outside contractors and to NATO/MoD staff, contract conditions that often discourage innovative solutions, defence industry's restructuring, companies merging or allying both nationally and internationally and finally concentration on delivering short term, mostly financial, benefits.
- *Ill defined roles and responsibilities of the stakeholders*: There is seldom a clear single customer within NATO or MOD for equipment projects. A number of processes like defining the requirement for equipment, researching potential technologies, managing procurement projects and supporting equipment throughout its life are executed separately within NATO/MOD and furthermore not enough authority is delegated to those managing all the various stages of the equipment life cycle.
- *Difficulties of technology insertion*: Defence equipment is becoming increasingly complex and diverse, while the product life of current High Tech equipment has an estimated stable baseline of not more than 12 to 18 months for manufacturing and another 36 to 48 months for sustainment. This relatively short product life cycle has an impact on

spares levels and needed support equipment and requires planned technology updates through technical refresh and technology infusion.

The Life Cycle Working Group has found that many nations have identified the same problems as are stated above. They have taken action to correct those: for example, SMART PROCUREMENT and the creation of a single Defence Logistics Organisation in the UK MOD and the LIFE CYCLE INTEGRATION-initiative in the US DoD. Also the Defence Capability Initiatives (DCIs) and the NATO Armaments Review (NAR) has identified the need to establish closer collaborative links between all interested parties in the development and use of the Defence Systems.

Those initiatives all have in common a consistent focus on the System's Life Cycle. It is the group's firm belief that NATO should also develop a similar improvement program with at its core, ***Life Cycle Management*** (LCM).

Where should NATO go and what should be its objectives?

The earlier list of symptoms is only a preliminary analysis of where our Organisation goes wrong. However before embarking on a major change program involving Life Cycle Management, CNAD will have to convince everybody in NATO to introduce LCM.

As part of any further initial steps towards introducing the concepts of LCM, NATO should make an analysis of its business and identify and quantify if possible the benefits. The latter will build a real case for change, which will contribute greatly to the definition of what changes are needed and for measuring accomplishments.

The objectives for introducing LCM in NATO should be:
- To establish a life cycle partnership between all stakeholders in a *project*.
- To have a total and shared view on the objectives of a *project*.
- To create seamless life cycle management processes that extend from mission analysis to product disposal.
- To ensure continuous technology refreshment by stressing preference for commercial and non-developmental solutions to mission needs.

What are the benefits of LCM to NATO?

LCM in itself will provide a "total", collective and shared view of the objectives of the *project,* especially - what and who is it for - and thus ensure complete customer satisfaction. This means that within LCM, the objectives of each phase in the life cycle will be defined contributing to that overall success and how they need to interact; that is, cascading the objectives and ensuring all future activity still contributes to deliver the defined return(s). This will be done through careful Mission and Investment Analysis:
- A strong capability for mission analysis will look forward in time to identify and prioritise needs before they become operational problems. We absolutely need to have a clear long-term vision of the way in which we expect our forces and their methods of operation to develop.
- A strong capability for investment analysis will ensure rigorous and impartial treatment of alternative strategies for satisfying mission need, while also achieving "buy-in" from the users who must live with the solution and the providers who deliver it.

But what is Life Cycle Management?

At its first meeting the Life Cycle Working group identified that to understand the scope of Life Cycle management in NATO one will have to define the term ***"System"***:

"An integrated composite that consists of one or more processes, hardware, software, facilities and people, that provide a capability to satisfy a stated need or objective".

Keeping in mind the definition above the Life Cycle Working Group agreed on the following definition for ***"Life Cycle Management"***:

"The management of a system, applied throughout its life, that bases all decisions on the anticipated mission-related, political, social and economic aspects of the system Life Cycle."

The study was focused on the mission-related and economic considerations. The duration or extent of the life cycle depends upon fulfilling the intended need, the complexity of the system, the environment in which it operates, and its life cycle cost.

Life Cycle Management will assure that the business processes and procedures used across projects are consistent and that there is effective sharing and co-ordination of resources, information and technology. Life Cycle Management is a holistic approach used to describe all the strategic, organisational and technological tasks that should assist in correcting the flaws of our current logistics systems, which were identified earlier in the second paragraph of this paper. The focus on Life Cycle Management will provide an optimal adjustment of our organisation, our business processes and our information systems to the demands of the war fighters and all other stakeholders.

Managing the total life cycle means ***the integration of the acquisition and logistic processes***.

Has LCM any relationships with other disciplines?

The Life Cycle Management approach clearly brings together (elements of) other disciplines such as:

- ***Systems Engineering and Integration*** (SE&I) which is a collaborative process to derive, evolve, and verify a life cycle balanced system solution that satisfies customer needs and expectations. SE&I provides a structured approach, typically consisting of hardware, software or networking, in a heterogeneous environment to meet business challenges, in other words LCM in the design and development of a system.
- ***Logistics*** that is defined by NATO as the science of planning and carrying out the movement and maintenance of forces. This definition clearly stipulates the pre-eminence of support to the war fighter. However in the broader context of Life Cycle Management, logistics could be considered as the life cycle management of resources for systems and operations.
- ***Total Quality Management*** (TQM) has the aim to ensure that each activity contributes to achieving the key objectives of the business and is carried out effectively (ref 8). Within NATO's Quality Management System this is done by integrating working processes, optimising internal and external interfaces, and developing good commercial relationships with industry (ref 9). Those are the essential elements of LCM.
- ***Supply Chain Management*** is a new business strategy that is getting a lot of attention in our industries which can be defined as (ref 10) - co-ordinating, scheduling and controlling procurement, production, inventories and deliveries of products and services to customers. It includes all the steps you do everyday in your administration, operations, and logistics department(s): Processing information from your customers to suppliers. The **Supply Chain** itself is considered to be all inter-linked resources and activities needed to create and deliver products and services to customers.
- ***Integrated Logistics Support*** (ILS) is a management function that provides planning, funding, and functioning controls which help to assure that the system meets performance requirements, is developed at a reasonable price, and can be supported throughout its life cycle. It is an integral part of LCM and supports Logistics and SE&I.
- ***Concurrent Engineering*** is a systematic approach to creating a product design that considers all elements of the product life cycle from conception of the design to disposal of the product. And in doing so defines the product, its manufacturing processes, and all other required life cycle processes such as logistic support. It can be considered as the application of LCM during the Design Phase.

What are the enablers to make LCM a success in NATO?

What are the key enablers in a strategy to implement LCM successfully in an organisation like NATO? The Life Cycle Working Group has recognised that it is important to assure that all of the enablers should be looked upon as being mutual supporting, and that the real benefit is achieved by closely integrating them.

It is just a summary of a few of the enablers towards lowering the total ownership costs while at the same time satisfying the war fighter's operational and readiness requirements. The Working group considered them as particularly important and each should be assigned to analytical teams for further evaluation and defining ways to accelerate implementation in NATO.

Many of the enablers have already been discussed and recommended for implementation by various NATO-groups. One of the firsts steps in a strategy for LCM-implementation should be to map:

- NATO-initiatives against those enablers,
- the enablers against the Strategic objectives to-be-determined in a NATO-vision on LCM,
- the NATO initiatives against the various-groups and/or organisational units concerned.

This might lead to assigning some of the work of the analytical teams to existent NATO Working Groups and focussing the work on the strategic objectives.

To make a success of introducing LCM in NATO the following environmental factors will need to be in place:

- ***Implementation of a unified business process methodology***: The research and findings from the last 20 years (CALS, EC/EDI, CIM, BPR, TQM, and others) have shown the need to analyse why and what an organisation does before embarking into any change process. Also it is necessary to relate the things one organisation does to what is done in another organisation. Therefore a uniform business process methodology across the whole of NATO, industry, business partners and supplier base or in other words the stakeholders should be developed and implemented. This will lead to a series of more integrated and seamless business practices in a virtual business environment or extended enterprise. This will be supported by business systems that provide full support for the war fighter across multiple functional areas like logistics, and procurement and acquisition.
  The use of a international standard such as Standard 15288 - Life Cycle Management, System Life Cycle Processes - from the International Organisation for Standardisation (ISO), and discussed under Chapter 5, as a framework will be a step in that direction.
- ***Implement Change Management***: The implementation of LCM will affect the whole organisation. It is the ultimate responsibility of senior management to align the organisation's people and culture to the new LCM-strategy. It is a complex and difficult task. Lessons from the past teach us that, in general, insufficient attention is given to managing resistance and to skill people to operate in the new environment. Indeed:
  - Employees must do different things, make different decisions and perform in different ways.
  - New networks of suppliers, manufacturers, distributors and customers will have to be forged.
  - Suppliers will have to react with their own change process.
  - Alliance partners will need to share the same vision.
  - New infrastructure across these networks must be built or reconfigured including computer systems, distribution centres, factories and support organisations.

  To make matters more challenging, this must all be achieved in a framework of continuous operations: systems cannot be shut down while we remodel.
- ***Implementation of an Information Policy***: A typical Supply Chain has two sub-chains. The first sub-chain is the product supply chain. The second sub-chain, the information chain, is more complex and more difficult to grasp.
  The critical logistics issue is how to make sure the right information is available in time, at the right level of the organisation and at the right level of detail needed for effective

decision making. Therefore NATO will have to agree on a Reference Model for Information Management. This is a description of all of the possible software components, component services (functions), and the relationships between them (how these components are put together and how they will interact).

Integrated systems further assume some level of agreement on data definition, meaning and context, agreement on common, reusable business objects (or network service), a common business language and agreement on common interfaces. One of the underlying data-modules is the product engineering data. Also in that field ideally the product data representation should conform to a single standard. Two standards are emerging here: the Object Management Groups Product Data Management (ref.5) enablers and the International Standard Organisation's Standard for the Exchange of Product Data (STEP, ref.6).

A concerted effort is needed to define and implement an Information Policy that ensures that NATO's IT investment priorities cover the exigencies of implementing the LCM-concept. The challenge is the timely and accurate access and integration of logistics data across units and combat support agencies throughout the world providing reliable asset visibility and access to logistics resources in support of the war fighter.

- ***Development of Performance Measurement Systems***: *US Air Force Chief of Staff Gen. Michael E. Ryan said "Now, quite honestly, if you can't describe it, and then measure it, we probably ought to question whether we ought to be doing it".*

  This fundamentally describes why we need Performance Measurement. Measurement needs to be viewed as a process for obtaining vital insight into the progress, products, and/or processes of the project or system being developed and used. This insight helps the decision maker to make more informed decisions, identifying deviations from plans earlier, thus allowing mid-course corrective actions when it is less expensive to make them.

  At all levels, managers should be able to evaluate their actions and productivity. Managers have to know if a program is on schedule or at risk. If a program is not on schedule, managers need to know that problems have been resolved and that the program will meet desired objectives.

  The performance measurement system should provide descriptions of the key elements to evaluate each business area and process and should be linked to the overall planning system. The key to satisfying this requirement is the ability to deliver summarised data that directs managers to areas that require further investigation.

  Performance Measurement should be an essential part of our change-to-LCM-strategy, where the measurement process needs to be viewed as a process for obtaining vital insight into the progress toward implementation of LCM.
- ***Implementation of an Improved Requirement Management***: The management and development of large complex systems presents many challenges to system managers like the ability to ensure that the needs of the users are satisfied and to ensure easy maintenance and enhancement during their deployed lifetime. These systems often change and evolve throughout their life cycle: this makes it difficult to trace the implemented system against original and evolving user requirements.

  Requirements establish an understanding of the user's needs, and also provide the final yardstick against which the final result is measured. Requirements management consists of information capture, information storage and management, and information dissemination. Key to the success of any requirement management process is requirement trace-ability. Requirement trace-ability is a technique used to establish and maintain relationships between requirements and design and implementation of a system in order to manage the effect of change and ensure the success of the delivered systems. Every system-characteristic should be traceable to the user needs: this is an essential element of a Quality Management System and therefore of LCM.
- ***Application of Advanced Cost Management Techniques***: Defence managers need to know their costs and be motivated to improve quality and reduce costs. Efficient and effective product support requires the ability to view costs from a variety of perspectives (e.g., by weapon; organisation; ownership; base or installation; mission area or warfare task; and function, process, or activity). Project Managers need accurate product costing

(that links Operation & Support costs to weapon systems) to select a provider among organic and commercial organisations. Supply Chain Managers will need accurate product costing to establish optimum network configurations to develop plans to integrate vendor and organic activities. NATO must develop plans to implement life cycle costing to support those managers.
All NATO services and Agencies should therefore be encouraged to share resources and develop a common framework of terms and definitions for activities performed throughout NATO. Common definitions for functions and processes will enable benchmarking and sharing of best practices and serve as a foundation for more sophisticated modelling. The concept of Total Cost of Ownership should be an integral part of the way to manage systems.

- ***Implementation of Total Asset Visibility*** (TAV): This is the capability to provide users with timely and accurate information on the location, movement, status, and identity of units, personnel, equipment, and supplies. It also includes the capability to act upon that information to improve overall performance of NATO's logistics practices. TAV should include in process, in-storage, and in-transit business processes. In-process assets are items that are being either repaired or procured.
  Without this visibility, redundant materiel orders, inaccurate personnel accounting, and a general lack of confidence in the dependability of the logistics and personnel pipelines will continue to plague our forces.

What might a Life Cycle Management Model in NATO look like?

The Life Cycle Management Model is aimed at establishing a common framework for describing the life cycle of a system by a complete set of well-defined processes and associated terminology. The processes may be applied throughout the life cycle for managing and performing the conception, development, production, utilisation, support and retirement of systems. This is accomplished through the involvement of all interested parties with the ultimate goal of meeting NATO/NATO Nation’s needs and achieving satisfaction of all the stakeholders.
The Model may be used:

- ***By an organisation*** to establish an environment of desired processes that can be supported by an infrastructure of methods, procedures, techniques, tools and trained personnel. The organisation may then employ this environment to run and control its projects and progress systems through their life cycle phases.
- ***By a project/system***, within an organisation to select, structure, employ and perform the elements of the established environment. This mode may be used also to assess conformance of the project/system with the declared, established environment.

Keeping in mind what is stated above it is easy to see that system life cycle management can be partitioned into two distinct but interrelated aspects:

- ***Phases*** in the time domain; the partitioning of the system life cycle management into phases is based on the practicality of doing the work in small, understandable, timely steps. They, in addition, help to address uncertainties and risk associated with cost, schedule general objectives and decisions factors.
- ***Processes*** in the function domain; the partitioning of the system life cycle management into processes is based on the principles of modularity (maximal cohesive functions minimal coupling among processes) and of responsibility (a process is under a responsibility).

Figure 1: Generic representation system life cycle processes in a phase

The life cycle of a system begins with a conceptualisation of a mission need for the system, progresses through its realisation, utilisation and evolution, and ends in its retirement. This progression of a system through its phases is achieved as the result of actions, performed and managed by people in organisations, using processes for their performance. These processes, termed ***life cycle processes*** may be invoked at any time during the life cycle. The functions they perform are defined in terms of specific ***purposes*****,** ***outcomes*****,** and the set of ***activities***, which constitute the process. The detailed purpose and order of use of these processes throughout the life cycle is influenced by multiple factors, including social, trading, organisational and technical considerations, each of which may vary during the life of a system. An individual system life cycle is thus a complex system of processes that will normally possess concurrent, iterative, recursive and time dependent characteristics. Above introduces the system life cycle processes.

The system life cycle processes can be usefully seen as a series of four main processes (termed Enterprise, Management, Agreement and Technical area processes). These main processes operate within an integrated "continuous" process (System life cycle management) with milestones between phases where objectives are defined at the beginning a phase and major decisions like approval are made at the end of a phase. This synergy between, life cycle phases and the functional contributors is necessary to successfully meet the enterprise objectives, manage and perform technical activities and, ultimately, for systems to fully meet mission needs in a sustainable manner.

Process modelling is a valuable technique to document complex business process, eliminate ambiguity and highlight information flow. Application of one or more of such models depends on several factors. Among some of the more common ones are the ***scope***, the ***viewpoint*** and the ***objective***, which in the context of the proposed framework are:

Scope To establish a common framework for describing the life cycle of systems and to encourage organisations to see their activities from an overall NATO/NATO Nations process viewpoint instead of from a narrow functional viewpoint.

Viewpoint The viewpoint taken in the proposed model is that of the system life cycle Manager accountable for providing and sustaining the system through life in order to meet the NATO/NATO Nations objectives.

Objective The system life cycle process Model is a structured representation of the main activities associated with a complex system from the definition of a mission need through to disposal. It is intended to provide a reference and a common vocabulary to understand system life cycle management. Further it provides a basis for the development of an information architecture supporting the NATO system life cycle approach.

The generic and simple structure of the high level Model, shown below, has been used as the basis of the system life cycle Model. In the report (1) the Model has been expanded to show more clearly the detailed processes and breakdown of activities and the main inputs and outputs. Each life cycle process can be invoked, as required, at any time throughout the life cycle and there is no definitive order in their use. The structure of presentation in Figure 1 above does not therefore imply any precedence or sequence of application of the processes. The grouping (area processes), however, does reflect underlying models used in this document.

Typically, organisations distinguish between different areas of managerial responsibility and actions. Together, these areas contribute to the organisation's overall capability to operate. Within each organisation, a co-ordinated set of those area processes contribute to the effective acquisition, use and support of systems and by doing so contribute to achieving the overall organisation goals. This Model is based on the four primary organisational areas of responsibility, represented by the top level processes (see also Figure 2):

- ***The Enterprise process*** ensures that the needs and expectations of the organisation's interested parties are met. They manage the organisation's activities required to implement a system life cycle approach within the organisation, defining the strategy to be prosecuted and providing the necessary organisational support to the implementation process. They also provide a structured approach for defining specific organisation's investment in response to a mission need, ensuring the satisfaction of the organisation overall objectives.
- ***The management process*** evolves plans to accomplish project/system objectives, assess actual achievement and progress against the plans and control execution of them through completion. Unfortunately, they tend to operate within a discontinuous and changing environment, will be enacted by different stakeholders, performing multiple roles at different times and in most cases they have different, perhaps conflicting, business objectives. The challenge is how to optimise them to meet the overall project/system objectives. Integration management process is than required to ensure that the various management processes elements are properly co-ordinated. It involves making trade-offs among conflicting objectives and alternatives.
- ***The Technical Process*** defines the actions that transform the needs of stakeholders first into a product and then, by applying that product, to providing a service as, when and where needed in order to achieve stakeholders satisfaction.
- ***The agreement process*** is than used to achieve inter- and intra-organisation trading between different areas of responsibility.

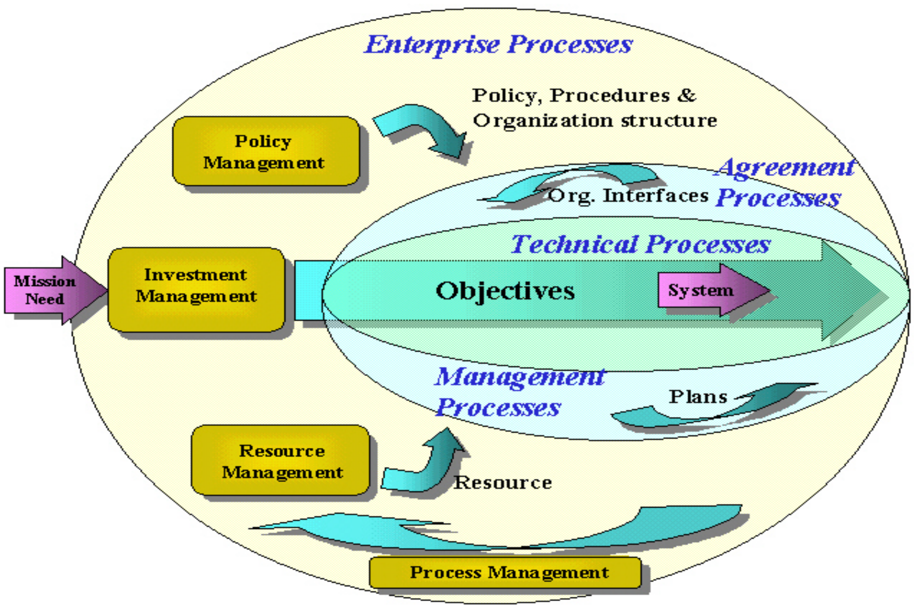


Figure 2: The high level Life Cycle Management Model

What is happening in NATO: Present and future?

Life Cycle thinking is not entirely new in NATO. The concepts have been adopted by several activities. The most important ones are described hereafter:

The SNLC is the lead committee of DCI SL9, which looks to improve procedures for co-operative logistics planning and management and enhanced co-ordination between the relevant planning disciplines. An Ad-hoc Working Group led by SILCEP and with participation of other NATO groups (NC^3A, NATO CALS, NAMSA, etc…) is developing a NATO Policy on Co-operation in Logistics.

The Group of National Directors for Quality Assurance (AC/250) has not only been focused on Quality, but through it's work and through the International Standardisation Organisation, considers the ***Process Approach*** as a main principle to Quality Management. In its new AQAP-100 (Allied Quality Assurance Publication – 100) it recommends that the organisations of the life cycle participants should establish, document, maintain and improve effective and economical processes for each life cycle phase. Organisations can use international standards, as appropriate, to align and tailor the applicable processes with the organisation's structure, goals and business strategy. These standards may also contain the criteria that confirm the successful execution of the processes.

SAS-028 is a Task Group under the SAS-panel (Studies, Analysis and Simulation - panel) of the Research and Technology Agency (RTA). This SAS-panel has recognised the need for an improved Life Cycle Cost Model with the ability to view costs from a variety of perspectives and tasked the mentioned Task Group to develop a *generic* life cycle cost breakdown structure with associated definitions.

As a result of the NATO Armaments Review (NAR) initiative, the NATO Committee for Armaments Co-ordination (NCAC) has been created. This committee is pursuing better co-ordination among armaments-related activities and programmes, by examining the Consolidated Alliance Capability Goals (CACGs) and the development of Alliance Co-ordinated Armaments Requirements (ACARs). By better Requirement Management this committee wants to improve visibility on armaments programmes.

The NATO CALS Management Board (NCMB) has given us a focus on Information and has at all times championed the need for a consistent definition of information needs to support the Management of the System Life Cycle.
A special NCMB working group on Metrics has laid the foundation for consistent Performance Measurement in NATO.

The Life Cycle Working Group has specifically addressed the difficulties in the management and engineering of complex systems. Almost every present-day system contains, is modelled by, and/or is supported by computer technology. This increasing utilisation of the computer has led to new opportunities but also to new problems. There are several factors contributing to these problems. Some are due to the inherent differences between hardware, software and humans. Others are essentially due to a lack of harmonisation and integration of the involved disciplines such as science, engineering, management and finance. As a result, the working group has felt it necessary to demonstrate the need for a common framework to be used to improve communication and co-operation between diverse disciplines and so enable modern systems to be created, utilised and managed in an integrated, coherent fashion. The Life Cycle Management Process Model (tailoring of the draft ISO 15288 – Life Cycle Management – System Life Cycle Processes) provides such a common framework.

How could LCM be taken forward in NATO?

LCM will need a holistic approach, involving the whole Alliance. So it is very important to have:

- Senior management involvement.
- A clear vision on what to achieve with LCM in NATO.
- The whole NATO organisation targeted for Life Cycle Management, which means the change to LCM, being an overall approach, can not be delegated to a single office.

So the Life Cycle Working Group recommends an action plan for

- ***The near term***: From previous paragraphs in this paper it should be clear that there are two issues which need to be addressed most urgently to introduce successfully the concept of LCM:
  - NATO must be perfectly clear about what it want to be achieved by the introduction of LCM. What is its scope: NATO HQ, the Agencies, or all NATO projects?
  - A common framework of terms and definitions for activities performed throughout NATO: Is NATO going to adopt the developments in the International Standardisation Organisation?

  Therefore the Life Cycle Work-Group has proposed the following actions to be taken by NATO:
  - ***To establish a policy framework for LCM*** under the responsibility of a Senior Management Committee (SMC) for Life Cycle Management by developing clear targets for Life Cycle Management in NATO. This SMC should be lead by a high NATO authority, having direct impact on the NATO-organisation. It is recommended that the SMC be supported by a group of experts drawn from the areas of CNAD, SNLC and NC^{3}Board. This committee should do the following with the above results:
    - ♦ They should seek endorsement by NATO top management and formalise them as a NATO Publication.
    - ♦ They should organise a NATO-wide conference on LCM where NATO presents the vision of LCM and where participants form techniques and methodologies to implement LCM.
  - ***To establish a terminology framework*** by setting up a team to further investigate the use of the draft ISO15288. This team must convince the whole organisation of the benefits of this standard to be. It must investigate its impact on other NATO publications.
- ***Medium term***: The SMC must set priorities for introducing LCM in NATO. They might want to investigate re-structuring of NATO HQ organisation and might want to establish Working Groups to align organisational functions with Life Cycle Processes. Therefore the SMC should:
  - Start with setting up a Team to develop a set of Life Cycle Management Guidelines regarding :
    - ♦ The complete tailoring of ISO 15288 and document it as an STANAG.
    - ♦ The Revision of NATO's Phased Armaments Programming System (PAPS).
    - ♦ The targets for Life Cycle Management in NATO (i.e. Performance Measurements, Information Management, Life Cycle costing, etc.) and formalise them as NATO Publications
  - Secondly organise training and workshops on Life Cycle Management to:
    - ♦ advertise above products,
    - ♦ provide awareness on tools and enablers,
    - ♦ instruct the personnel and provide the adequate skills; the aim is to form teams, which can implement LCM in specific projects.
  - And finally should seek the implementation of its products in Pilot Programs.
- ***Long term***: The SMC should use Performance Measurements to monitor implementations and to adjust targets of Life Cycle Management. And last but not least the SMC should monitor new developments in technology and Business Management.

The final recommendations to CNAD by the Life Cycle Working Group in order to make the transformation to LCM a success for NATO are:

- To investigate the broadest possible participation of other organisations: all NATO HQ Divisions, the NATO Agencies, NIAG, and most of the WG working under NATO authority. Therefore CNAD should task the NATO CALS Management Board to present this report to SNLC and NC³Board and distribute the report to all the NATO stakeholders involved in Life Cycle processes.
- To task a high level Committee under CNAD to analyse this report and in particular investigate, in close co-ordination with SNLC and NC³Board, how these actions for the near, medium and long term could effectively be implemented in NATO.

What are the present activities?

The report "Life Cycle Management in NATO" (1) is the result of the work of CNAD's Life Cycle Working Group led by the NATO CALS Office (under the auspices of the NATO CALS Management Board). The CNAD, through their NADREPs (National Armaments Directors Representatives) who have approved at their 12th March 2001 meeting the Life-Cycle WG report and the related recommendations, has tasked the NATO CALS Management Board to continue this important work and:

- present this report to the SNLC and the NC3 Board and to distribute the report to all relevant NATO stakeholders involved in Life Cycle processes;
- investigate, in close co-ordination with other appropriate NATO bodies, how the roadmap for implementation of Life Cycle Management proposed in the report (see paragraph above) can be effectively implemented in NATO.

References

1. "Life Cycle Management in NATO", a report to the Conference of National Armament Directors, 25 September 2000, edition 1
2. "UK Strategic Defence Review", supporting Essay on "Procurement and Industry", http://www.mod.uk/policy/sdr/essay10.htm
3. "Optimising Return at the Programme Level: Through-Life Management", a paper for APLS/CALS Europe 99, Tony Munton, IBM Consulting Group.
4. "UK SMART Procurement Handbook", http://www.mod.uk/policy/spi/handbook/front.htm
5. PDM Enablers - Joint Proposal to the OMG in Response to OMG Manufacturing Domain Task Force RFP 1 - Doc mfg/98-01-01 - http://cgi.omg.org/cgi-bin/doc?mfg/98-01-01.
6. ISO 10303 - Industrial automation systems and integration.
7. AAP-20 - Handbook on the Phase Armaments Programming System (PAPS)
8. "Implementing Total Quality Management" - Lesly & Malcolm Munro-Faure - Pitman Publishing - 1992.
9. The NATO Policy on an Integrated Systems Approach to Quality through the Life Cycle - AQAP100-Ed3.
10. "Supply Chain Management: Where Today's Businesses Compete" - By Bill Hakanson - Supply-Chain Council - http://www.ascet.com/ascet/wp/wpHakanson.html.
11. "A roadmap to change" - by B. Herreman - available from the NATO CALS office.
12. "A new way of Working - Managing Defence Systems in the Information Age" - A NATO CALS Publication. - June 1999.
13. "Product Support for the 21st Century" - Report of US DoD - July 1999.

Click here to view PowerPoint presentation; Press Esc to exit

Life Cycle Costing in a Commercial Style Accounting Regime as it Impacts U.K. MoD

Julian Burridge[1]
SPS/CF/DEV&POL
Mail Point 187, Elm 1b
DPA - MoD
Abbey Wood, Bristol
BS34 8JH
United Kingdom

SUMMARY

This paper reviews the drive towards commercial style accounting in the UK MoD and the requirements for life cycle costing. It then discusses the thrust towards whole life costs and how this is defined in the UK. The meaning of Cost Of Ownership, economic and financial appraisal is explained and what steps are required such that the various required outputs can be derived. Newly developed tools and processes are described that will help the MoD to realise the objectives of improving decision making and budgeting.

BACKGROUND

1. Way back in 1995 the UK’s Chancellor of the Exchequer issued a White Paper "Better Accounting for the Taxpayer's Money". In accordance with the White Paper, accounting and reporting changed for most government departments. From 2001 planning and control was to be on a resource cost rather than ‘just’ a cash basis to get better visibility of consumption. This was introduced under the title of Resource Accounting and Budgeting (RAB).

2. The main thrust was to introduce commercial style accounting, used by industry for many years, into government organisations. However, the sheer scale of the Ministry of Defence's activities, the range of purchases, number of assets, their use and management, provides a huge challenge when introducing resource accounting. Indeed the National Audit Office’s Comptroller and Auditor General’s report[2] showed that there were still areas of progress to be made.

3. All Governments Departments including the MoD will show year on year what has been achieved (outputs) against specific objectives and the costs of doing so. They will produce an Operating Cost Statements, Balance Sheets, Cash Flow Statements, Main Objective Analysis, Output and Performance Analysis. With the introduction of RAB, the Treasury wants MoD to focus on the cost of resources used as they accrue and not just the cash spent in pursuit of the Department's objective(s) over a given period of time.

4. What is more, the organisation needs to be able to measure the net worth of assets as part of the overall financial management. Assets are therefore re-valued annually and to make sure that these valuations are correct, every five years an independent review is undertaken (a 5 yearly review is currently underway at this time that will value half a million items of equipment). This review identifies gross replacement costs employing at least two different valuation methods.

[1] The author is grateful for contributions from Duncan Barradale of DSTL and Wing Commander Barney Hubble of the DLO WLC IBT

[2] Report of the Comptroller and Auditor General on the Accounts of the Ministry of Defence : Departmental Resource Accounts 1999-2000 issued February 2001

Paper presented at the RTO SAS Symposium on “Cost Structure and Life Cycle Cost (LCC) for Military Systems”, held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

5. Smart Acquisition (SA), formerly known as Smart Procurement, was introduced into the MoD following the Strategic Defence Review to emphasise a whole-life approach in requirement setting, procurement management, support management, disposal and whole life costing. Projects are now managed by Integrated Project Teams (IPTs) who are empowered to manage their projects whilst bringing together the main stakeholders. These IPTs are 'suppliers' of capability (usually by bringing into service new ships, aircraft etc.). They have clearly identified Capability 'customers' within MOD headquarters who provide funding and direction to the IPT for all procurement stages of the project life cycle. The Equipment Capability Customer (ECC) is responsible for developing and managing a balanced and affordable equipment programme. To do this properly requires a high level overview of the Department's whole life costs. A Second 'Customer' has responsibility for ensuring that the Directors of Equipment Capability (DECs) are provided with appropriate guidance on all components of delivering military capability. They also have responsibility for defining outputs from the IPT and monitoring them, during the in-service project stage. In SA there should be a greater willingness to identify, evaluate and implement effective trade-offs between system performance, whole-life costs, annual cost of ownership and time.

6. All of the above impacts life cycle costing because financial analysis on a RAB basis introduces a number of challenges. To operate effectively there needs to be an understanding of all budgets impacting platforms on a regular and consistent basis.

COMMERCIAL STYLE ACCOUNTING

7. Cash accounting provides only a simplistic view of the financial position. To trade off between departments and agencies requires information that can only be provided by full resource accounting since it allows managers to take a broader view of their finances. It also allows them to assess more clearly the financial implications of their plans and operational decisions. A 'notional' charge, Interest On Capital (IOC), currently at 6%, 'encourages' groups to reduce their holdings and transfer ownership of assets as quickly as possible to the user. Users need to identify surplus items to reduce their IOC costs and accrual accounting means that costs are accounted for when committed not when bills are paid (naturally bill payments are still important so both are recorded). The Government will, in due course, control Departmental (including MoD) spending on a RAB basis.

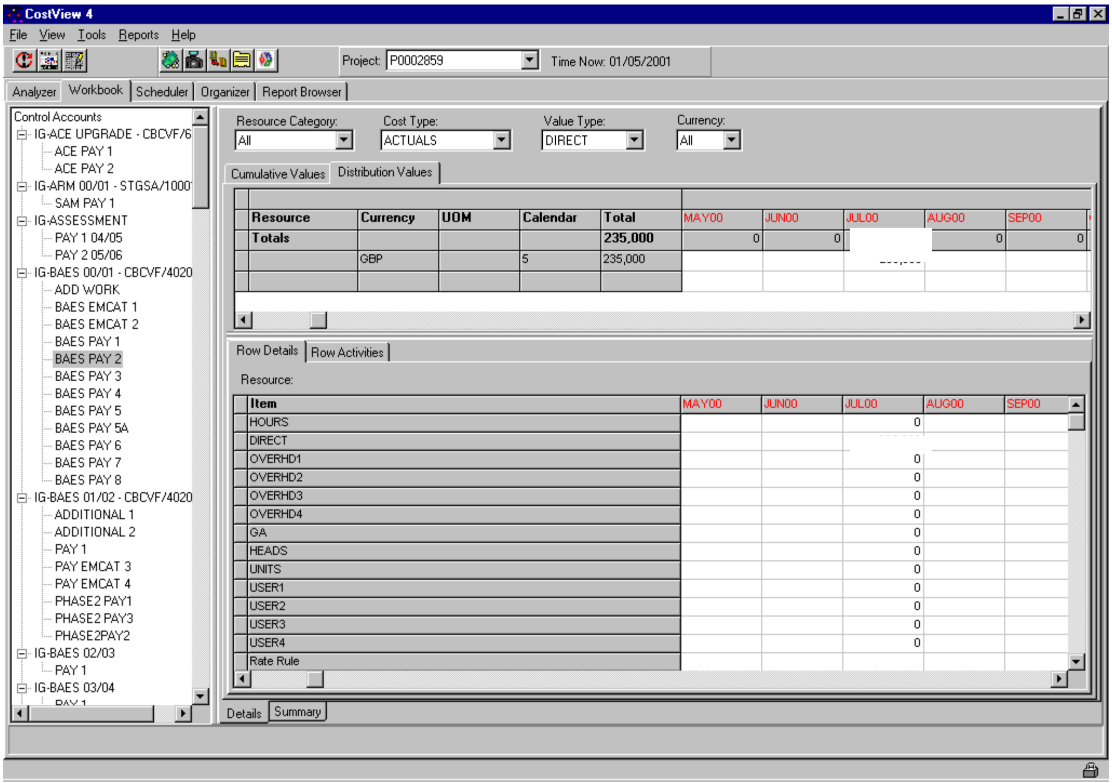
TERMINOLOGY: LIFE CYCLE COSTING, WHOLE-LIFE COSTING, COST OF OWNERSHIP, TOTAL OWNERSHIP COSTS

8. Life Cycle Costing has been used for many years to describe the process by which costs associated with each phase of an equipment's life, development, procurement, operation, support and disposal are brought together to address questions of 'best buy'. Affordability however was judged against cash budgets that, by and large, were set for periods far less than the anticipated lifetimes of equipment. Currently the equipment programme covers 10 years in detail while the Short Term Plan (in RAB format) only looks forward 4 years.

9. When RAB was introduced it was anticipated that full cost communication would be achieved. Once all contributors to the costs of acquisition were known, direct costs (e.g. buying the equipment and spares) plus attributed costs (e.g. share of dockyard facilities, Service manpower etc.) could be combined. These costs, because of the inclusion of 'indirect' (to specific fighting equipment) elements, are considered to be 'whole life costs'. In other words they would represent closer to 100% of the attributable, to a capability or equipment, costs. By combining the 'attributable' elements the cost of role capable force elements could be determined. Unfortunately this can not be currently achieved in an automatic process through the financial system which reports costs 'vertically'. Each budget holder, in an organisation, reports costs 'upwards' but not necessarily their contribution to equipment or force elements. To do this a number of initiatives have been put in place and the following paragraphs discuss these.

10. In the Defence Procurement Agency a computer tool set called ASPECT (A Set of Performance Enhancing Computer Tools) enables procurement teams to manage their projects. It is an integrated package 'glued' together from Commercial Off The Shelf (COTS) Tools like Oracle Purchasing. One of the latest releases (Release 4), the finance package, allows IPTs to manage their equipment costs on an accruals and cash

expenditure basis. As such it allows for the allocation of resources to work breakdown structures and records both accruals and cash expenditure. At present ASPECT is rolled out to the teams in DPA but it is anticipated that it will be made available to in-service project teams once funds are made available. A screen from Cost View is shown below.



11. The Total Ownership Cost (TOC) concept as produced by NATO group 6[3], seeks to widen the scope and coverage of costs rather like COO but (naturally) not including the UK approach to financial reporting.

12. In the UK therefore Whole-Life Costing can be thought of as an umbrella process for all the activities such as budgeting, investment appraisal, decision support etc. that require a life cycle costing exercise. Cost Of Ownership which is consistent with RAB will provide a summary of life cycle costs by platform, from which affordability can be assessed. It is therefore planned to be the primary metric used to for new programme approvals and current (in-service) equipment projects.

INTRODUCING COST OF OWNERSHIP

13. The UK have set out to satisfy these requirements by using the annual ‘Cost Of Ownership' (COO) as the preferred WLC metric as it allows an annual, comparable measure of performance as well as the construction of a lifetime cost figure. The main benefits of forecasting, monitoring and managing COO from ‘prediction to actuals’ is that it contributes to the optimisation of military output by improving the Departments view of the overall costs of proposed solutions to meet military capability. It should improve the assessment of affordability through-life, leading to more informed decision-making. It should also enhance the Department's ability to make decisions - trading-off cost, time and performance between individual equipment projects within, or across several, capability areas.

[3] NATO GROUP 6 Specialist Team on Ship Costing

THE ORGANISATIONS INVOLVED

14. Since the majority of whole life costs are expended in the operation and support phase of a programme the Defence Logistic Organisation have taken the role as 'Champions of WLC'. Working under a Whole Life Cost Steering Group the community is working towards improvements in methods and tools. The WLC Integrated Business Team is charged with introducing the COO methodology over the next 18 months and the largest MoD equipment projects will be reporting their through life COO in the Major Projects Report for 2002 onwards. SPS as part of the Defence Procurement Agency supports project teams and Centre customers with Combined Operational Effectiveness & Investment Appraisal (COEIA), investment appraisals, modelling and budgeting. The Defence Science and Technology Laboratory (DSTL) Analysis Group help the 'Centre' i.e. central customer, with studies to address such issues as balance of investment (e.g. the right mix of Unmanned Air Vehicles (UAVs) and ground based surveillance vehicles).

TECHNICAL ISSUES

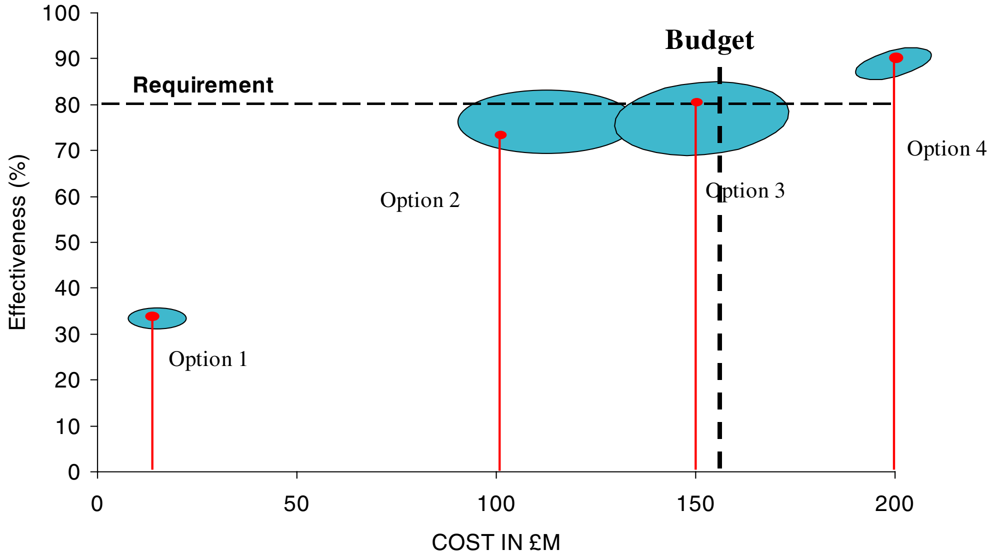
15. Life Cycle Costs have been considered key to procurement decisions for many years in a number of NATO countries. Whilst resources in terms of people and cash were considered, often only the marginal (difference) costs between options have been considered. Firstly, because of the practical need to set aside sufficient funds to pay industry for Tanks, Aircraft and Ships and the spares and maintenance required to support them. Secondly because Defence Ministries are large organisations it has been difficult to gather data on resource consumption or communicate costs effectively between budget holders.

16. Economic Appraisals undertaken by Government bodies such as MoD, 'are concerned with the well-being of the country'[4]. As such they address opportunity costs (alternative use of assets or resources) but not simple transfer payments such as taxes (e.g. Value Added Tax) that 'move around' the economy. Economic analysis may be simply summarised as addressing the costs and benefits of options to 'UK Ltd' and is not, necessarily, therefore concerned about precisely which part of the Department's budget is impacted. Any common costs not impacting the decision may be excluded to simplify, and hence reduce the costs of, the exercise.

17. Financial Appraisals however include all cash flows and transfer payments and hence assess affordability. In the UK, Cost Of Ownership will provide this viewpoint. In financial appraisal, costs need to be split by budget holder, so they know their contribution, by phase to understand the significance over the life cycle and by major 'input' cost category (manpower, stocks purchased, in year expenses etc).

18. Provided that in any assessment of options there is an affordable option (comparing COO for the new and existing capability will provide this check) then the IA should be able to identify any alternatives that offer better value for money. In the UK the primary means of distinguishing between options is cost effectiveness. The chart below shows four options with point estimates and ellipses that represent uncertainty in the costs and effectiveness forecasts.

[4] Joint Services Publication number 507 : MoD Guide to Investment Appraisal and Evaluation



19. Like industry the MoD will continue to use both economic and financial appraisal techniques.

REQUIREMENTS FOR TOOLS AND PROJECT PHASES

20. The move to Cost Of Ownership will help to provide data on existing platforms and hence inform modelling. To support the initiative new tools and approaches have or are being developed. They need to be directed and designed at the whole life cycle of equipment and capability.

21. Early in the project life cycle, studies need to address the capability gap, the numbers of equipment or platforms required and the technologies that can help to fill the gap to offer best value for money. This requires strategic cost models that can provide a capability to look at the 'big picture'.

22. Once a project team has been formed and given a user requirement, the focus turns to the performance, cost and time envelope of various options that will meet the requirement. Forecasts of costs for new equipment and platforms are needed. This requires models that have a holistic view and can provide a 'what if' capability.

23. When the preferred option is identified, industry is generally asked to compete for its supply. Assessments of these bids are based on life cycle cost analysis and need to address economic and financial treatments. Cost figures need to compliant with rules on Investment Appraisal set out by the Treasury and at the same time provide the data by which budgets can be agreed for the long term operation and support of the assets.

24. For in-service equipment a forecast of the costs for the remaining life are required. Whilst any in-service equipment, not nearing the end of its service life is generally considered to be in the middle of the 'bathtub' in respect of reliability, major cost drivers are driven by 'change milestones' caused by events such as overhaul, deployment, updates and safety reviews. Towards the end of equipment life, ageing effects may increase support costs or reduce availability. Not all equipment goes out of service on a particular date so phasing out expenditure depends on the introduction profile of new equipment or capability. Delays to new equipment can result in extra funds being required to continue support of legacy equipment. The following are necessary considerations to establish the nature of each cost element when making the forecast:

Is it?

- Substantially constant regardless of operation and support volumetric changes
- Simply related to operation and support volumetric changes (may use scaling factors)
- Complex relationship due to changing patterns and cost drivers over time (e.g. maintenance concept changes, ageing effects, etc.)

- Periodic, event driven, recurring or non recurring (e.g. mid life updates, refits, deployment changes, peace keeping etc.)
- Changing over time (e.g. ageing)
- Step changes (macro economic impacts)

OUTPUT (ACTIVITY) COSTING AND INPUT COST CATEGORIES

25. The number of potential activities performed in development, production, operation and support etc. may be considered almost infinite e.g. Prototype manufacture, Maintenance at 1st line, Basic Training, Post Design Support, Storage, Recruitment etc. In the UK a generic Cost and Resource Breakdown Structure (CRBS) has been promulgated to provide a consistent set of activities for equipment cost forecasts.

26. In support based organisations, overheads are often a major part of the total cost (as they now are in manufacturing). Any traditional costing system which recovers overheads only in proportion to direct labour costs or time may be of limited use as a management tool because activities other than direct labour may be more closely linked to the generation of costs. In Activity Based Costing (ABC) costs are linked to products via the most appropriate 'cost drivers' not solely by direct labour. Once Activity Based Costing is fully operational it may prove possible to generate cost drivers from this data.

27. Contributing elements of input cost (i.e. resources consumed in producing the activities) can be reduced to just 9 categories.

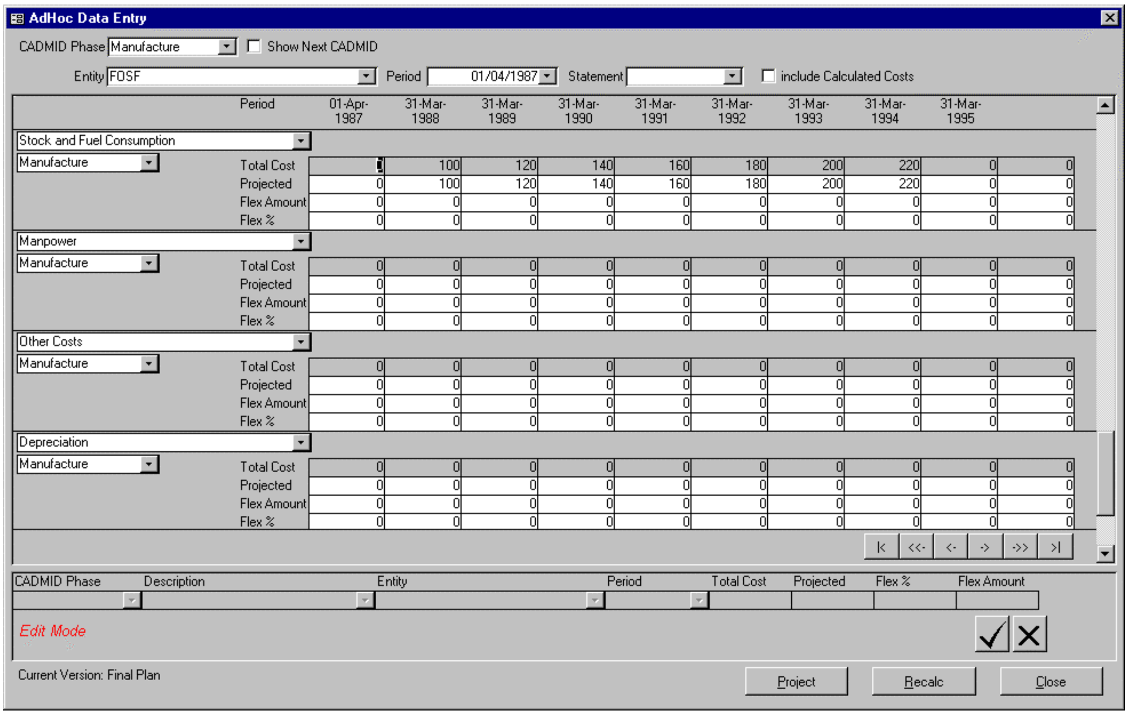
- Manpower expenditure (internal staff)
- Payments on contract
- Development expenditure and intangible assets
- Assets in the Course Of Construction (ACOC)
- Other fixed assets
- Capital spares purchase (e.g. spare aeroplane engines)
- RMC (Raw Materials and Consumables) GWMB (Guided Weapons, Missiles and Bombs) purchase
- Stock and RMC purchase
- Other expenditure

28. To enable COO figures to be compiled therefore, translations between activities and input cost categories need to be achieved. Whilst in many cases, this is a reasonably mundane exercise, a number of activities are a combination of various cost inputs.

TOOL SETS

29. This part of the paper will cover tools that can assist in the process and will describe/demonstrate their operation and applicability to project phase.

30. **COO TEMPLATE**. This is used as a depository of costs from various sources and allows a Cost Of Ownership to be compiled for complete platforms and Force Elements. These include Activity Based Costing (ABC) Output costing tools and direct user entry from business plans etc. The screen shot below shows a data entry screen for Flag Officer Surface Flotilla's contribution during the CADMID phase of Manufacture to (say) Type 42 Destroyers.

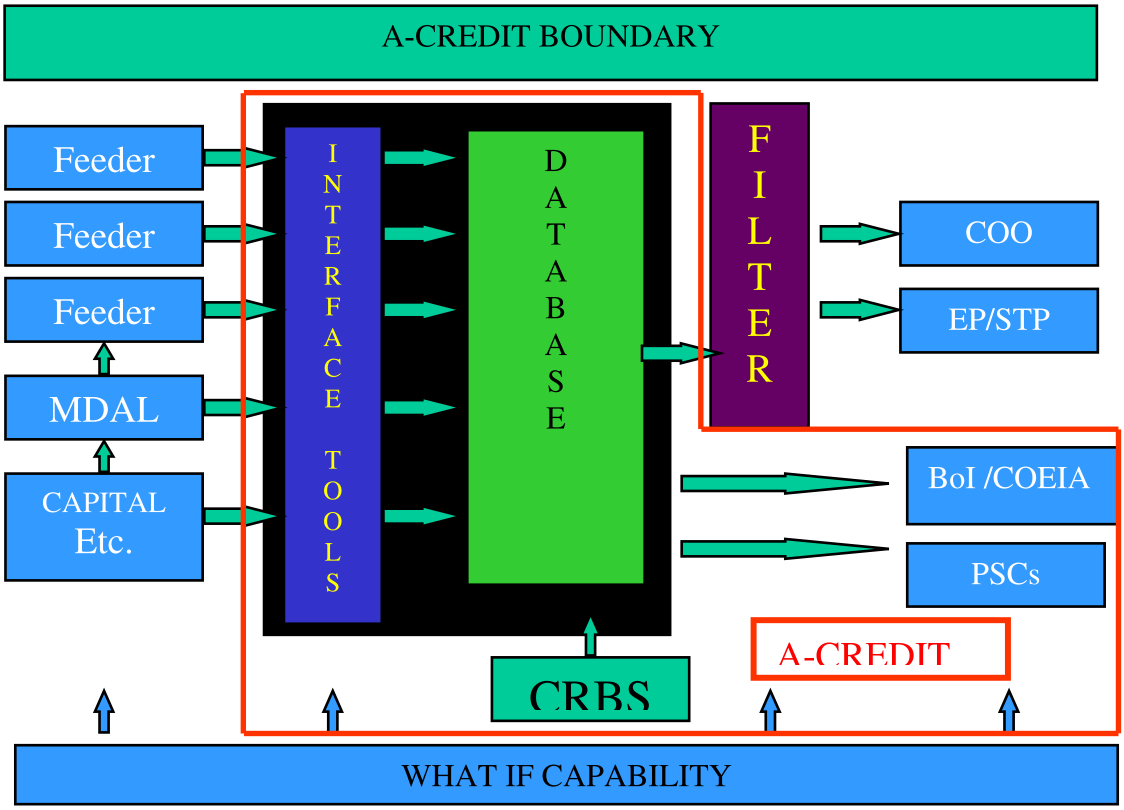


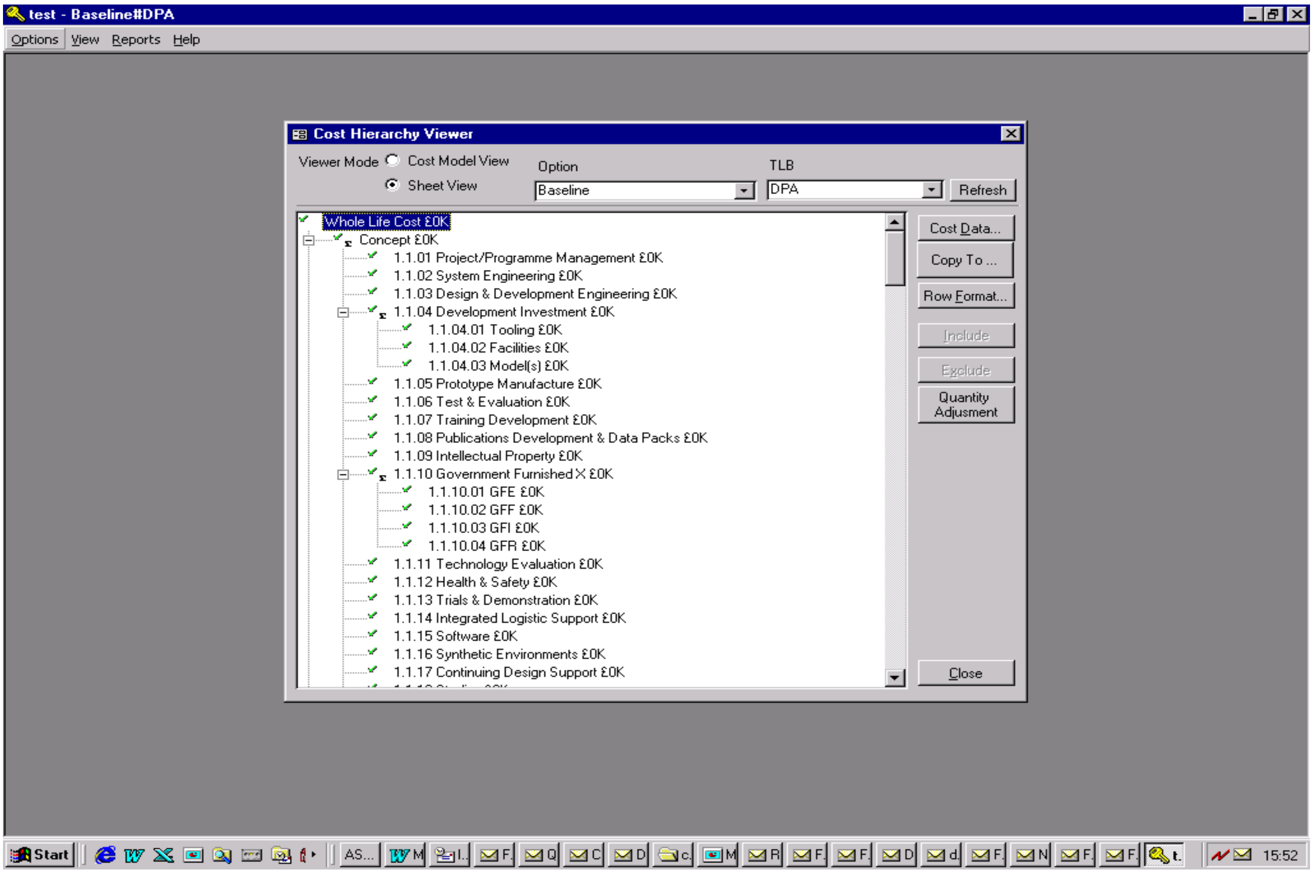
31. To arrive at a Cost Of Ownership for a Type 42 platform (excluding weapons systems) requires inputs from 8 'entities' who are stakeholders, project teams, front line users etc. In this example it includes Major Warships IPT, Fleet Wide Systems, Marine Aux/Environ Sys, Marine Dom, Monitor & Steer, Marine Electrical Systems, Marine Fire/Fluid/Power, Marine Propulsion Systems, Flag Officer Surface Fleet.

32. **Options and Affordability Tool Set (OATS)** The WLC IBT are developing a database that will combine the outputs from all of the COO statements to provide a Departmental Capability force element Cost Of Ownership summary.

33. **Metify** Within the MOD a COTS package called 'Metify' is being used to collect activity based costing data. It allows departmental accounts to be allocated to activities and thereby derive 'cost drivers'. This particularly helps organisations pin point their main cost drivers so that efficiencies can be made. The COO template incorporates a link to Metify so that it can 'read in' data directly. Over time Metify may well identify sets of cost drivers that can be used to populate models. However, this may require a common 'language' or terminology set so that the results can be used for life cycle costing.

34. **A-CREDIT** The Automated Cost Resource & Data Integration Tool combines costs from various sources – both commercial and bespoke feeder tools and direct input. It maintains a database of costs including 'sunk costs' tagged to a common Cost Resource Breakdown Structure. It helps to carry out the mapping process mentioned in the paragraph 'OUTPUT (ACTIVITY) COSTING AND INPUT COST CATEGORIES' above. A diagram is attached below to show A-CREDIT's links to forecasting tools (Feeder) and the required outputs. A screen shot shows part of the detail recorded in the database.

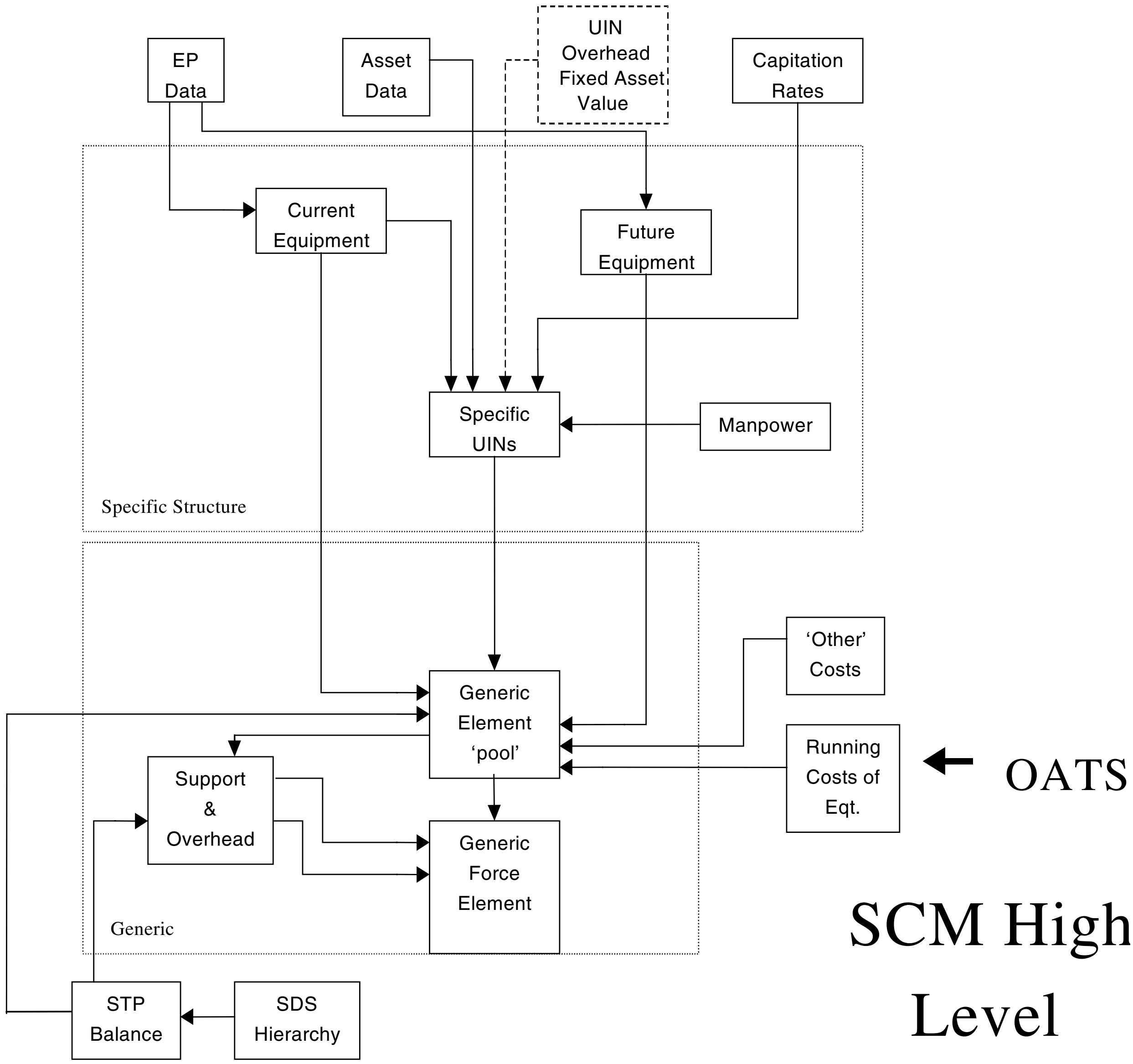

A-CREDIT BOUNDARY
Feeder
Feeder
Feeder
MDAL
CAPITAL Etc.
INTERFACE TOOLS
DATABASE
FILTER
COO
EP/STP
BoI /COEIA
PSCs
A-CREDIT
CRBS
WHAT IF CAPABILITY


test - Baseline#DPA
Options View Reports Help
Cost Hierarchy Viewer
Viewer Mode
Cost Model View
Sheet View
Option
Baseline
TLB
DPA
Refresh
Whole Life Cost £0K
Concept £0K
1.1.01 Project/Programme Management £0K
1.1.02 System Engineering £0K
1.1.03 Design & Development Engineering £0K
1.1.04 Development Investment £0K
1.1.04.01 Tooling £0K
1.1.04.02 Facilities £0K
1.1.04.03 Model(s) £0K
1.1.05 Prototype Manufacture £0K
1.1.06 Test & Evaluation £0K
1.1.07 Training Development £0K
1.1.08 Publications Development & Data Packs £0K
1.1.09 Intellectual Property £0K
1.1.10 Government Furnished X £0K
1.1.10.01 GFE £0K
1.1.10.02 GFF £0K
1.1.10.03 GFI £0K
1.1.10.04 GFR £0K
1.1.11 Technology Evaluation £0K
1.1.12 Health & Safety £0K
1.1.13 Trials & Demonstration £0K
1.1.14 Integrated Logistic Support £0K
1.1.15 Software £0K
1.1.16 Synthetic Environments £0K
1.1.17 Continuing Design Support £0K
Cost Data...
Copy To ...
Row Format...
Include
Exclude
Quantity Adjusment
Close
Start
15:52

35. **Strategic Cost Model** The Strategic Cost Model (SCM) will provide a representation of the whole life cost of Defence Force Elements (FEs) out to a 30-year horizon, including the attribution of support hierarchies. This will allow the user to model the impact in cost terms of changes to force structures or packages, and the potential impact of the adoption of different equipment or systems on the overall Defence budget. The primary output of the SCM is output resource consumption against FE. However, alongside the output costs, the SCM also needs to provide:

- Cash based costs, in order to provide an estimate of the total defence expenditure. This has two purposes: First to provide validation of the SCM output against actual defence expenditure; and second to provide guidance as to cash requirements for future years and for alternative force structures.
- Input costs for major cost headings down to unit level. These are required so that alternative force structures can be examined by building up costs from the bottom-up. In the absence of cost communication they also provide validation because costs can be examined against easily recognisable assumptions about manpower, equipment numbers etc.

In order to provide the total cost associated with a force element, it is necessary to account for the whole cost of ownership of any systems and equipment together with the cost of resources consumed, including an appropriate share of all support functions and corporate services. In other words, the SCM seeks to provide aggregated output costs against force elements. A diagram is attached below.



SCM High Level Structure

CONCLUSION

36. Introducing commercial style accounting into life cycle costing is not going to be a simple process. However some good progress has been made and this paper shows some of the newly developed tools and techniques that will support the process. It is recognised by all concerned that there is a substantial investment in training, tool support and resources to operate and maintain the databases and systems put in place. However, despite the large size of the Department much progress has been made whilst, at the same time, realising savings in internal operating costs expected from the taxpayer as a result of the ending of the cold war, the so called 'peace dividend'.

The views expressed are those of the author and do not necessarily represent those of the United Kingdom Ministry of Defence

Click here to view PowerPoint presentation; Press Esc to exit

Cost Estimating and Forecasting in the New Era of Smart Procurement

Dr Brian John Hilton
Senior Lecturer
Cranfield University
RMCS, Shrivenham
Swindon, Wilts SN6 8LA
United Kingdom

Tel. 44-1793-785456
Fax. 44-1793-785771

Abstract

This paper reports on research [1]on the future cost estimating and forecasting challenges facing defense and aerospace. It shows that cost estimation is now a critical and changing capability for the UK Aerospace and Defense industries. As defense changes and downsizes projects are more infrequent, more risky, more dependent on new processes and support systems all less permissive of high error rates and profit margins. MoD and industry are responding by restructuring their processes, focussing on new business opportunities and widening the scope of cost information and support. Critical to this is support for Integrated Product Teams (IPTs) in estimating trade-offs between design and supply chain and ownership costs.

Our work suggests significant added value from joint research by academia and industry. Traditional techniques for using data in Cost Estimating Relationships (CERs) do not take into account the simultaneous interaction between designing to deliver a particular through life capability to an available budget when one is willing to trade-off affordability against capability, reliability and support costs.

Our work explores the potential of best commercial practice in production and distribution to contribute to lower cost military capability. Strenuous efforts are being made on this, “smart procurement”. If successful this will have a significant impact on cost and so estimating.

Our work distinguished between three levels of impact by:-

1) utilizing modern international distributional networks available to all
2) using modern "lean" techniques within organizations
3) introducing new production process and materials

If defense manufacturing could work on a shorter cycle of flow based procurement, say over 5 to 10 years, things could change dramatically. The current cycle is 15-20 years using batch procurement. This batch procurement cycle has high initial costs followed by considerable inventory, updating and sustainment costs. Best modern commercial procurement practice requires a flow of frequently purchased reliable equipment requiring less in-service support. Could this be achieved in defense? Until now no investment has been made in the costing resources to test this hypothesis. We provide a theoretical basis for doing so

However, defense departments are monoposonistic buyers driven by political and military, not commercial, imperatives. It is thus difficult to envisage how they can access all the benefits of commercial practice. The paper considers the potential impact in principle of these methods on defense procurement costs and so estimates. It then hypothesises on the means by which the results desired might be achieved given the described constraints. A lack of historical defense data on the impact of these methods is a barrier to defense based research. The consequence is

[1] conducted over 1999-2000 for the UK MoD and the UK Engineering and Physical Sciences Research Council (EPSRC)

Paper presented at the RTO SAS Symposium on “Cost Structure and Life Cycle Cost (LCC) for Military Systems”, held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

that estimators have to use commercial analogies. These then have to be modified to recognize the non-competitiveness of the defense context.

Specific new areas of research suggested by all this would be:

1) The extent to which commercial practice can work in military procurement;

2) To model the impact of processes on cost, as opposed to capability on cost;

3) The support implication of Commercial Off The Shelf (COTS) components and systems

INTRODUCTION

The private commercial sector is adopting new approaches to the management of design, development and production. These have led to new product and process technologies. These use and produce value within a new revolutionary framework. This crucially impacts on cost (Delbridge, and Lowe, 1996). Can it be applied to defense? If so, how will this impact on defense costs and so cost estimating? This paper sets out to answer these questions.

In commerce one does not have to contend with defense's endemic and extensive systems integration problems. One also does not have its peculiarity of politically driven monopsonistic demand. A key issue for defense today is thus the extent to which it can adopt best commercial practice and cut costs despite these barriers to its use. The benefits achievable in the wider industrial context are already evident (Womack and Jones 1996). They are considerable as a consequence of faster development and more capability deliverable per dollar. However can one expect these benefits to be fully achievable in defense given its technical and socio-political context? The present administration is the US's DoD clearly believes they can (Cohen, 1997).

The approach used is prevalent throughout the Atlantic community. It has acquired the name "Smart Procurement" (SP). This exploits what in commerce has become the philosophy of "lean production". This seeks to lean out production costs by auditing productive activity against the criteria set by the value it adds for the final customer. The argument is that if an activity does not add such value then it should cease. In defense the value added is the state's wish to maximize its potential to use lethal force per dollar spent to legitimate political ends.

Philosophically and practically "lean production" requires customers' demands to pull production down through a well specified energy minimizing flow of activities. Each should add customer value. There should be no local accumulation of energy absorbing stock. This is distinct from supply driven systems. These achieve economies of scale by pushing production up through a sequence of costly energy batch processes designed to maximize the rate of flow through each

So as to minimize unit processing costs. This is only achievable at the expense of large pools of stock waiting for processing at the rate are required to minimize processing costs within each stage. To achieve its ends SP must therefore ensure it:

1) Creates a steady flow of demand not infrequent, stock creating, batches of it.

2) Adds value to politically useful military operational capability in each procurement stage: research, development, manufacture, use and disposal

To achieve these SP has to be integrated with the operational context in which the materiel of war will ultimately be consumed. It therefore needs to synchronize procurement with the needs of military operations across the envisaged spectrum of possible conflict.

In effect this means that SP, like the "battle space" it is now envisioned supporting by the "Revolution in Military Affairs"(RMA), needs to be based on the integration of systems across. This is what we might call the "battle-sphere": the weapons systems and their users, the battle-space in which they are used in conjunction with other systems and the industrial, research and social systems that enable all this to occur. In the defense industrial context supporting the RMA it is thus essential that the design, production, storage and disposing of weapons systems optimizes political-military value across their whole life cycle.

This paper sets out to categorize the changes catalyzing SP and highlight their potential impact on cost. It will consider also their likely rate of propagation given current constraints and defense’s capacity to ease them. Our focus is the agenda thus implied for cost estimating professionals. The evidence used is all in the public domain. This seems to indicate that the historical cost base on which current estimates are constructed is fast being eroded. This means the profession has to develop new approaches, it is, but are they coming on fast enough?

The whole basis of SP is that costs can be cut using commercial sources and methods particularly if defense accepts commercial not military specifications. Then “Commercial Off The Shelf” (COTS) “Dual Use” technology can be exploited. Then it is argued the commercial sectors, for its own benefit will absorb a significant proportion of development costs. We shall explore whether this is a reasonable expectation?

Lean manufacturing and distribution networks encapsulate the philosophy of “lean thinking” commerce uses to achieve the described ends (Womack and Jones 1996) This incorporates Just in Time logistics (JITs), low inventories, zero delivery defects, flexible small batch production and so co-operation throughout a supply chain where products are designed not only for use but for limiting the consumption of non-renewable raw materials, manufacture, reliability, ease of servicing and ultimately disposal. This requires the chain from raw material extraction to re-use or disposal as a single system over which all costs should be minimized no matter by whom born (McDuffle and Helper, 1997). A key issue for this to be achievable is incentive. The pay-off may be in one part of the network but additional costs in another. These network components are likely to be under different ownership and so control.

The distributed processing and flexible military fighting procedures on which the RMA is based are fundamental to this paper. The digitized battle-space brings changes doctrinally and technically. These challenge the cost estimator even before we look into the process of manufacture and supply. Integrated "Command and Control" C^2 makes it possible to economize on one platform’s capability by using the capacity of another. To this can be added stealth and total battlefield visibility. Together these create a huge increase in military productivity allowing the use of massive destructive power from a safe platform of action, e.g. Apache Longbow. This complicates cost and operational effectiveness analysis not least by hugely increasing the logistic burdens required to sustain the fighting power now capable of deployment.

This new battle-space is more sparsely populated with human beings. This has deep implications for the nature of warfare and so costs. We can now take people away from many of the hazards of war. These lower costs by eliminating the need for the protection currently built into each platform involved in combat. This is already reality for reconnaissance with the increased use of drones.

It is now possible to make a choice as to whether target acquisition, or even attack, should be managed on or off a weapons platform. It is envisaged that an army unit could lay of an attack instantaneously to an, artillery battery, a helicopter, a fixed wing aircraft, a ship's guns a few miles of the coast or a submarine based cruise missile 500 or 600 miles way. This has significant implications for the wider international marketability and so cost sharing possible for a weapon system. A weapon system that relies on expensive centrally provided off-platform command, control, guidance and computation or acquisition technology will not be widely affordable. For example on the joint

US UK JASF a US design decision that increased its weapons load at the expense of onboard command and control would leave JASF's other customer, the UK, with a problem. Have a platform only useable in a combined US/UK operation or accept a bill, financial or military, to integrate UK STA technology onto a consequently less lethal platform.

These operational implications of new technology should be seen in conjunction with the problems for the SP concepts of evolutionary development based on incremental technological insertion.

The idea is that this would allow military technology to stay in step with the now faster advancing civil, COTS, technology. SP seems to believes that technology insertion and so the incrementally procurement of capability can be achieved at the same time as one lengthen the time a platform concept remains in use. This lessens technological risk. It also spreads development and set up costs out over time and more extended, but individually smaller, production runs. This attenuates estimating errors. Error bounds grow exponentially on extrapolation. In IT product life-cycles are as little as eighteen months. Technological and therefore cost extrapolations can then be limited to a similar period.

In the described circumstances it is clear that costing by analogy must be problematic. First if defense has not yet used a commercial practice no direct historical basis exists in defense from which to construct an estimate. Second if commercial data were used directly the very different market structures from which it springs must throw doubts on its defense relevance.

With no "actual" costs to measure estimates must use analogy. There are four bases for this. Each has virtues. Each has problems. They are: -

1) the past,
2) experience elsewhere,
3) a plan extrapolating from the former two,
4) creative vision not evidently rooted in experience.

Our argument suggests that future cost estimates can be based only on the last. This requires the simulation of the processes of production, distribution and war fighting, i.e. "synthetic environments." However these are rarely created from imagination they are generally embedded in a substantive matrix of practice. These model what might be possible as opposed to what is demonstrable so. Research exists on this in the USA [2].

In thinking about cost in the holistic imaginative way we have described acquisition costs clearly can not be separated from other costs up and down stream. However even when taking this very broad brush view of a project envisaged one would still have failed to take account of significant costs. One could wrongly consider acquisition in isolation from other costs. Many of the changes we have outlined are not found at the level of project costs nor even in the historically evident overhead of the organizations in which it is embedded. Significant socio-economic changes, effecting costs, are also occurring at the industrial and infra structural level. We thus have to consider the effects of the change described on the cost environment at three levels: societal, the enterprise and the project. We will deal with each in turn.

First there exists an increasingly sophisticated global network of industrial support activity providing finance, research and development, design, production, distribution and marketing for all types of products and enterprises. We need to consider the impact on defense project costs of this increasingly sophisticated low cost global commercial support infrastructure.

[2] NASA is funding a cost estimating project based Weaks and Barrett (1998).

Second defense production is increasingly a process where the key inputs are produced by many distinct entities. The final result is merely integrated together by one, in the defense case, the "prime contractor". The delivered result is thus produced by a secondary, "virtual", organization for which the prime contractor is merely the impresario.

Thirdly we need to take cognizance of the impact of new materials and production and development methods on directly attributable project cost.

This paper considers the impact on cost of change at each of the above levels. After considering these it takes cognizance of the extent they can penetrate defense. We then consider what barriers exist to their implementation in defense and how these can be lowered before exploring their significance for estimating. Japanese companies led by Toyota [3] have demonstrated that all this can work. In the defense context we have to ask: -

1) Are there defense examples that can form the basis of estimates?

2) Will the new destroy the estimating utility of existing knowledge?

3) Will "smart procurement" lead to a seamless join between commercial and defense practice making analogies from commerce sufficient to defense need?

Even the strongest advocate of SP could not expect affirmative answers to all of these. A monopsonistic buyer, such as a defense department, dealing with a few large prime contractors, can not put itself in a position analogous to that pertaining in a commercial competitive market. If it could, cost estimating would be an irrelevance. The best estimate would be market price. We are thus left with the question of how one might adjust analogues from the commercial world, based on lean manufacturing and JITs experience, to the monopsonistic reality of defense

THE IMPACT OF INFRASTRUCTURE CHANGE ON COST

General Nature of Infrastructure Changes

The impact of infrastructure change on the costs of commodities such as food, clothing, cars and IT has been large.[4] The INTERNET and associated e-commerce are fundamentally changing infrastructure costs forever.

The word processing system and computer on which this paper is written is indicative of such business process changes. An icon at the top of the page can be clicked to allow what is written to be instantaneously transmitted across the world using the modem card inserted into a slot at the side of the machine. This electronic communication is cheaper and incomparably faster than the mail it replaces.

The technical limitations to the universality of its use are slight. Inexpensive truly mobile phones do not yet exist but soon they will. However even now an oilman working a field in Siberia, two hundred miles from a phone line, can have a daily satellite video conference with his partners on Wall Street regarding their customers demands that day. This determines how much oil he pumps. Oil need only flow from the well head when such demand "metaphorically" pulls it from the ground. This obviates the need for extensive tank farms at wellheads, ports, oil refineries and delivery centers.

The global co-ordination of production and distribution now possible eliminates the need for significant stock. This includes that in the process of distribution, i.e. in large expensive high-risk oil

[3] "The Machine that Changed the World", Womack, Jones, & Roos (1990).
[4] In defense jargon, multi-layered Integrated Logistics Support (ILS) is fundamental to best practice.

tankers. Such infrastructure change has a dramatic impact on cost and choice. The competitive pricing it ensures lowers costs further. This creates an even greater demand for variety of types, means, sources, and quality of supply.

The commercial distribution and electronic data interchange systems making such value added possible is too expensive for states to replicate. United Parcel Service's (UPS) aircraft fleet is the biggest in the world. They are major truck and warehouse owners. Their volume of business ensures unit costs lower than anything achievable even by government

Good in-house orchestration of logistics can produce world beating competitive advantage. One case is that of Caterpillar's success in its fight for market dominance against Komatsu of Japan (Bartlett, 1991). Komatsu set out to beat Caterpillar in the supply of large construction machines; comparable in their chassis and power trains to the heavy armor used by the military. Arguably Komatsu's equipment became as good, or even better than Caterpillar's. However they did not displace Caterpillar from its lead position. Caterpillar had and has a highly effective distribution chain. This intends that spare's be deliverable anywhere on the surface of the globe occurs within 48 hours. Civil engineering contractors faced with hefty penalty clauses or oil companies not pumping oil can not afford unavailable equipment. Komatsu has failed to match this service and so has failed to displace Caterpillar from its lead.

Caterpillar's success has not escaped the attention of others: for example the UK company Land Rover. Their commercial market place overlaps Caterpillar's. They now use Caterpillar's distribution system. In commercial games of war, errors may not lead to death but they can cause bankruptcy.

Commercial survival now depends on design trading-off and the cost of after-sales support. Komatsu's failure to overtake Caterpillar underlines this.

Modern supply and distribution allows one to operate wherever in the world it is best to do so. In the limit with stabilized demand one need carry no stock outside that in the delivery pipeline and only manufacture products in response to specific demand. This requires a new approach to manufacturing, "lean manufacturing" - the topic of section 4.

However for such technological advance to be sustained at the rate now evident requires process control concentrated in a few suppliers, e. g. UPS, INTEL and Microsoft. They achieve scale economies (volume over time) and scope (volume over space) leveraging low unit costs sustained by a steady pull of demand. This supports the huge initial investments in IPR, people, plant and equipment corporations like INTEL, Microsoft, UPS and Caterpillar need.

To minimize risks such companies take an incremental approach to product development. The aim is a payback period of not more than 2-3 years. A developmental revolution is not possible on such a life cycle. Intel's 84X86 series of microprocessors and Microsoft's MS-DOS/ Windows series are both examples of the benefits of such evolutionary development.

The Impact of Infrastructure Induced Change on Defense Costs

The infrastructure changes described impact on costs in many ways, including the cost of costing[5]. Software production is now geographical dispersed. The DOD's "Defense Reform Initiative" (Cohen, 1997) insists the US government use UPS and Federal Express' systems in preference to its own.

Part of the recent administrative reforms of the US DoD has encouraged the materiel commands of all three services to base much of their procurement systems on "electronic commerce" (Cohen

[5] The author is aware of a small consulting firm exists producing software cost estimating tools, one partner lives near Danebury, USA, one in Brighton, and an other in Munich.

1997). This allows orders to be sent direct to suppliers. They then deliver direct to military units. This saves on DoD owned storage and distribution systems. A recent paper[6] indicated cost savings on retail stock (about 1/12 of DoD stocks) of $40 for every $1 spent on UPS or FedEx.

For defense to access these advantages it needs to use Commercial Off The Shelf (COTS) items. On economies of scale grounds alone these can be so much cheaper than tailor made defense items that the argument for COTS is compelling. It is already accepted as the source of many electronic components.

Cost and Security Limitations to the Use of Infrastructure Change in Defense

However, adapting COTS to defense can be more expensive than working to a defense specification. COTS also raise security issues on two counts, security of information and security of supply.

On the latter consider the case of DOD's use of UPS or FedEx. This does not compromise the US's national security. These suppliers sustain most of their substantial assets and staff on US territory. In the event of war these can be requisitioned and conscripted. A small country wishing to ensure it can control its distribution and supply system in war may wish to deny defense access to such an approach. The result is then likely to be lower quality and higher costs.

On the former information security is costly, e.g. vetting, firewall construction, etc. Even without this defense might wish to deny itself access to cost effective practices used by commercial software firms, e.g. outsourcing to India. In addition the technical challenges in the commercial sector are now significant so increasingly high quality staff now often choose commercial over defense work.

Possible Actions to Exploit the Benefits of Such Changes Without the Costs

In total war, reliance on traditional systems must be in doubt. Arguably they trap defense into using expensive outmoded systems that may now be penetrated, or out performed, by cheaper commercial ones. As indicated in the absence of direct action to the contrary, generic commercial components are now so much cheaper that it is hard to avoid incorporating them in military systems. This generally puts defense costs on the same downward trend observable for production generally.

In operations less than war the practical advantages of such systems may outweigh their security disadvantages. In the Gulf War PCs were bought off the shelf. In Bosnia commercial trucking is used regularly and the American's have used commercial communication systems.

THE VIRTUAL ORGANISATION AND COSTS

Introduction

Systemic thinking also impacts on the organization of production, the key idea being the "virtual organization". This is manifest in the role now seen for prime contractors.

The globalising business process linking distinct production capacities together, as already described, underpins the "virtual organization". Cheap physical distribution coupled with highly efficient communication makes a widely distributed stockless network of manufacturers possible.

The Virtual Organization A Simple Example

Illustrative of this is the portable computer this paper is produced on. This was "made available" by a Taiwanese company, Twinhead. It was assembled and distributed in the UK. The screen was produced by Cirrus Logic in the USA, the hard-drive by Toshiba in Japan. The floppy was made in Taiwan and the modem in the USA by Apex Data. The microprocessor is an INTEL Pentium

manufactured who knows where. The mouse is made in Mexico. The software comes from all over the world but is integrated by Microsoft of Seattle USA.

Twinhead may or may not conceive of this package. However, they are the impresarios delivering it. The machine was ordered to an idiosyncratic individual specification on a Monday morning. The machine did not exist then nor were all the parts available to manufacture it. That evening the UK assembly and distribution center ordered the parts needed by FAX. Their suppliers then dispatched these parts by UPS, DHL, FedEx, etc. The next day they began to arrive. Assembly was started. As more parts arrived the machine grew closer to completion. Late Wednesday pre-delivery testing began. This was completed on the Thursday. UPS were then contacted to pick up the fully tested machine. It was delivered lunchtime Friday. This is “lean enterprise”. It is entirely demand-pull. The final product nor the parts to make it did not exist together until the customer demanded it.

By changing to demand pull for parts in the US, Toyota has reduced the time from manufacture to delivery from 11 to 2.5 months. For Toyota in the USA, 98% of car servicing and repair is completed within 1 day. In Japan itself, 98% of repair and maintenance actions are completed within 2hrs of demand using only 60% of the stock held in the US. (Womack and Jones, 1996)

Two Basic Features of the Successful Virtual Organization

Two key features that seem to lead to commercial success within the framework of the virtual organization are partnership sourcing (PS) and a commitment to outsource non-core business. All activity within an organization’s boundary uses up senior management time. Optimality requires that this be focused on a business's core skill areas. Management attention directed away from such core areas of activity defocuses on organization clarity of purpose and ultimately results. Markets, it is argued, produce very high-powered incentives to performance. A competitive market can ensure the cheap high quality supply of many non-core products and services. Arguably market incentives police achievement better than managerial effort, misdirected from what should be its main effort, the organizations core area of competence.

A set of skills core to an organization’s ethos can always be identified, (for an organization), eg. buying and retailing, everything else can be out-sourced to advantage specialists, each with their own core skills. Each member of a production and distribution network hones its core skills to a level of perfection not achievable in a vertically integrated organization. This ensures the right high quality products get to customers economically. In such a network each player is a high performer in his own right and uses his management to maintain focus on core activities only.

To ensure effectiveness in this process partnership sourcing (PS) is often used. This is designed to ensure that value is added continuously throughout in a supply chain. This requires trust between all those involved. This vitally includes the final customer. Post purchase customer utility is seen to be as important as a sale. If one were to competitively auction each link in a supply chain, one would destroy rather than create trust and so adds to cost. On the other hand in a vertically organized system, less able people tend to be recruited to non-core activities. Logically one would then expect their skills to be lower and managerial acuity in dealing with them less evident and so costs higher than might otherwise be the case. Evidence on this is limited. The converse has been the principal focus of research, i.e. what is the configuration of successful companies (Fruin, 1992).

In private sector virtual organizations professional purchasing management is a core skill. Effective partnership sourcing is a key part of that. Professional buyers choose a supplier on professional grounds based on critical performance criteria and endeavor to stay loyal to him no matter what. If a supplier is bad he is helped to improve before serious consideration is given to replacing him. This approach has proved cheaper than trust destroying compulsory competitive tendering (CCT).

Limitations to the Use of the Virtual Organizations Approach in Defense

In the CCT case the buyer has to pay the losers' as well as the winners' bidding costs. The cost of bidding on losing contracts has to be recovered. If one wins one out of five bids then four losing bids are costed into the winning one. With partnership sourcing not only are these costs saved but mutual interest can drive further gains in value and cost. Long term commitment allows the parties to invest mutually to eliminate costs. This is not viable with project by project contracting.

For probity reasons Western style administrations ban PS. Procurement agencies retain the trust-destroying, costly, but politically defensible, system of CCT. CCT ensures arms length relationship between the ultimate user and the supplier. The latter are dealt with through the legalistic, unfriendly and so costly process set up by contract's branches. Their principal and proper function is to ensure auditably fair, non-corrupt dealings with potential suppliers. Their focus is on fairness and equity between suppliers. It is not on efficiency and effectiveness. In contrast PS establishes close but tough relationships based on mutual interest. Anglo-Saxon style governance makes this approach almost impossible for government despite its cheapness in the absence of corruption.

The Efforts Made in Defense to Overcome The Limits so Set to Cost Savings

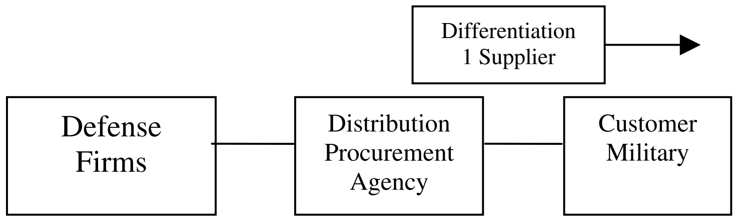
In defense many have seen recent reforms as advocating adversarial competition and CCT not PS. This view stems from its insistence on a tough professional relationship between buyer and seller. This, however, can be consistent with PS. The nature of the product procured by defense can be transformed so that CCT could be avoided and PS made effective indirectly. The trick is for the procurement process to change from that of a demander of specific tightly defined final products to the procurer of the services of, "prime contractors". These orchestrate the activities of others to satisfy the demands of defense. Primes have to be capable of integrating the best offerings in the market to provide the end desired not a pre-defined means of achieving it. Primes are not required to have the ability to manufacture a product only to effectively orchestrate its delivery of the service it is to provide.

To illustrate this argument we will use a model of microeconomic reality attributable to Michael Porter of Harvard Business School (Porter 1980). This uses what Porter calls the five forces driving business strategy. These forces have arguably been made moribund over much defense purchasing due to the use of cost plus contracting. Under this the choice of a weapons system is on the basis of a technical competition not price. We will now chart our interpretation of recent change in defense procurement practice using Porter’s five-force model. In effect we show that what has been done is to create a system of virtual organisations serving defense.

Porter sees the relationship between firms and their environment as subject to 5 key forces. He argues these necessarily drive business strategy: customer demands, distributor buying power, competitor actions, supplier’s value for money and new technology.

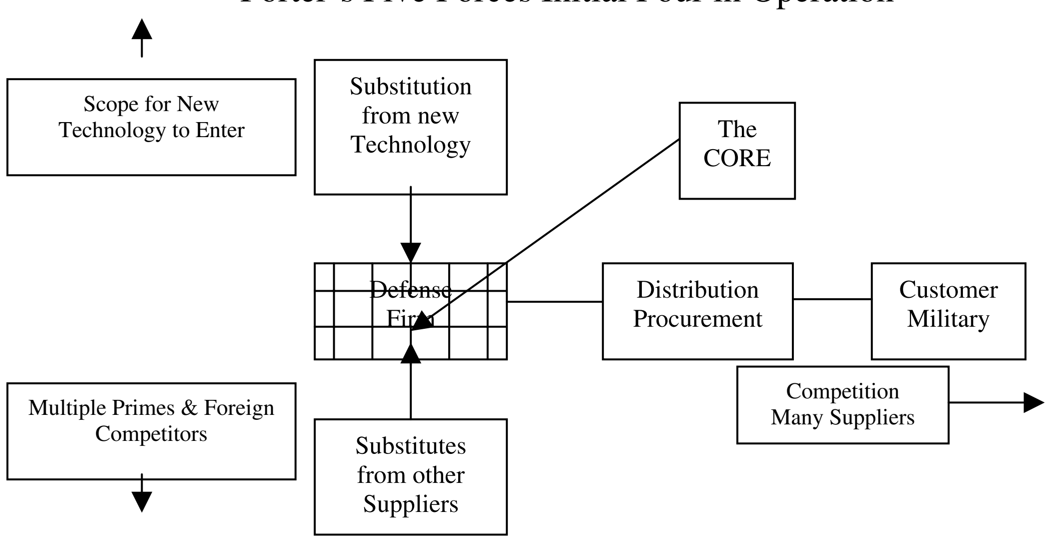
Prior to recent reforms the first two operated as illustrated in Figure 1. The customer is the politically directed military. The distributor is the defense procurement agency. Each supplier tries to differentiate his product to monopolize his position. This guarantees a return over and above minimal possible cost. Often the only organization capable of delivering what has been specified the supplier will be in a very strong bargaining position. The defense’s procurement agency is caught between this unique supplier and the military customer with a specification limiting the agency to one possible supplier. Suppliers will always seek to be in this position and so try to deal directly with the military to ensure a specification ensuring their success in this eg. for a fixed wing US manufactured aircraft capable of VTOL. If this is the requirement then there is only one supplier the procurement agency can go to.

Figure 1
Porter's Five Forces
(The First Two ineffective prior to reform)



The most important counter to monopolization by differentiation is the "cardinal points" specification. This specifies what is to be achieved not the means. This opens up credible competition to different technological solutions. A prime does not have to have all the skills required to deliver only the ability to orchestrate the activities of those who have. The defense procurement process then purchases an entirely new product, "prime contractorship". This is a generic not a product specific skill. Defense thus outsources the orchestration of procurement. This product is such that a number of organizations have the capacity to deliver it. This undermines differentiated, and so monopolized, supply. The consequence is that the procurement agency now faces a number of potential suppliers. This increases the credible competition faced. This effect is amplified by the existence of alternative technological solution to cardinal points specifications. This introduces potential credible competition from new technology. The defense procurement process thus specifies <u>what</u> is required rather than <u>how</u> and by <u>whom</u> it is produced. This changes the whole structure of the relationship between a defense department and industry. It inevitably alters contractor conduct and behavior. In so doing the performance obtainable for a given price/cost is improved. By these means multiple competitive sources of supply can be created even for development work or new systems. Figure 2 illustrates:

Figure 2
Porter's Five Forces Initial Four in Operation

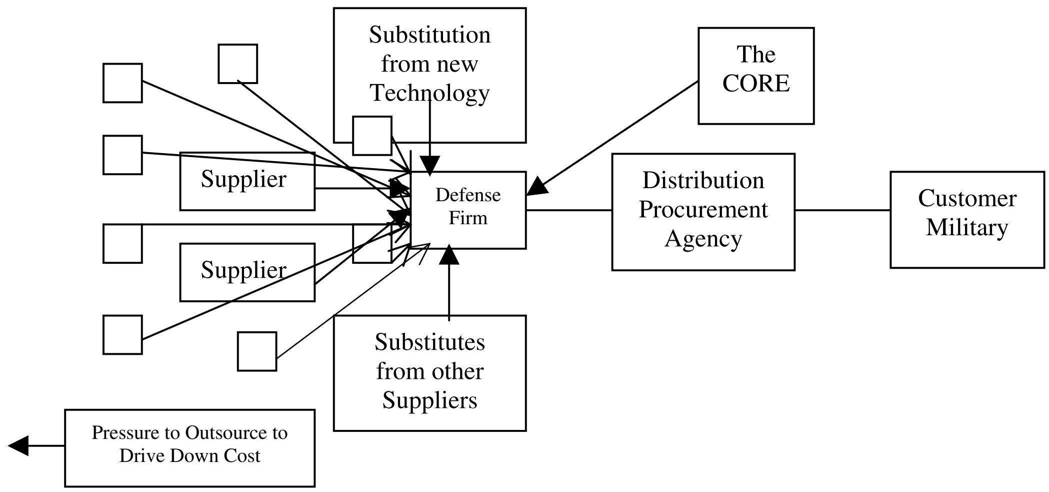


This allows cost plus contracting to be ended. With competitive tendering, fixed prices can be the norm. This has a virtuous incentive effect. Non competitive bidding leads to cost plus contracts, i.e. the supplier, audited by defense, calculates the cost of what is produced and gets a "fair" percentage return on that level of cost. This provides an incentive for activities to be brought in house that increase costs. With no fixed percentage return on cost there is no incentive to maximize them, by

retaining high cost in-house production. The incentive is reversed, i.e. to limit expensive in-house manufacture. This reinforces the managerial argument against employing non-core specialist. For equity financed firms pursuing shareholders value, outsourcing is then a necessity. The prime retains the lucrative and militarily significant "core" competence of systems integrator; all else is subcontracted.

Figure 3

Outsourcing Western Style with All Five of Porter's Forces in Action



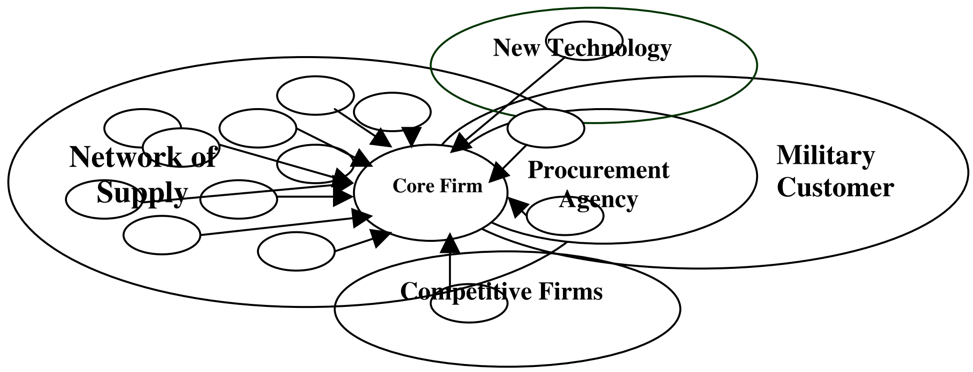
Trust: Substituting Win-Win for Win-Lose Games

This completes our analysis of the impact of procurement reform in the recent past. It does not include PS. As described competition is a zero sum game between the firm and defense agency procurement and between the firm and its suppliers. If one party in this chain gains the other is seen to lose. True partnerships require trust. This requires win-win games.

PS results from a genuine risk sharing partnership across the spectrum from raw material supplier to prime contractor. It is now said to be part of DoD policy (Cohen 1997). It is based on non zero sum win-win games. In a "bull", growing, or stable market everyone can win, supplier, prime contractor and consumer. In the private sector this results in the production and supply of the high quality reliable very marketable low cost products supplied by the Japanese car and electronics industry (Fruin, 1992, Wolmack, Jones and Roos 1990). To achieve this requires the "prime" to act like the central firm in a Japanese "Keiretsu" network. Firms like Toyota, Toshiba, Nissan, and Kawasaki build partnerships based on mutual commitment. They do this with cross investment of resources, physical and intellectual (Fruin, 1992).

Particularly Japanese "Primes" post staff at all levels to work with suppliers and in reciprocation suppliers post staff to them. The idea is to create an operational ethos based on genuine partnership rooted in a deep knowledge of each other's culture. This in turn is rooted in shared experiences of overcoming the unforeseen and unexpected in the tough minded but mutually advantageous manner indicative of good marriage. This kind of relationship can not exist with CCT and Western style outsourcing reliant on confrontational litigation. Lean manufacturing or JITs can not flourish in these latter contentious, often litigious, environments. The essence of JIT is trust (Dyer and Ouchi, 1993)

Figure 4
Japanese Style Partnership Sourcing



Arguably, implementing such reforms in defense could produce weapons systems very efficiently; conditional on yielding win-win, politically defensible higher returns for all stakeholders.

The shareholders in defense companies would get higher returns on the smaller investments that are then required to finance the individual parts of the virtual organization supplying a defense requirement. Thus the financing of the defense supply chain would be easier especially with one partner the final customer the state as a guaranteed power. The defense customer could even limit the political risks inherent in such partnerships by selling “put options”, based on a “cardinal points specification”, competitively to potential suppliers. This would eliminate the political risk to the supplier of cancellation. This would allow suppliers to get private finance for development and early production on the basis of commercial risk alone as they would have purchased an irrefutable contract if they can deliver to the cardinal points specification. This insures them against political induced changes of view on a project’s worth. Shareholders and lenders are then left with risks they understand i.e. a possible inability to deliver the product to the technical specification at the price contracted for. They can then act to balance market, managerial and technical risk against financial exposure. The political risks are taken out of the equation. They are left with the polity issuing the option. With such clarity in the distribution of risk sharper risk assessments are then possible and so each can then be more efficiently financed.

Workers as stakeholders are also in this win-win game. They get securer employment. Their employment is based on the functional service they supply not the requirements of a particular customer. If one user of the service or function disappears, there will be others requiring their function in other industries. In the vertically integrated organizations, eg typical of the past UK and French defense market, all functions, typing, stores management, etc., were locked into one customer their defense ministry. In a virtual organization, all employees have jobs ultimately dependent on their functional role in the production process not the continued existence of one particular customer for one particular product.

Risks in this system are attenuated and clarified creating room for win-win games. Technical progress is incremental, design is evolutionary and the commitment of any one group to a particular end result, while significant, will not be catastrophic if it fails.

Well done, this process produces greater VFM to the final customer (Ward et al, 1995). This is not achieved using a hard edged network of individuals and organizations playing zero sum market games but the co-operative fuzzy set of overlapping mutually advantageous relationships suggested by Figure 4. This produces benefits for all. These are deliverable by getting a proper balance between alternate approaches to organizing production. One uses the superior power of market incentives wherever possible. To be able to do this one needs to make an explicit specification of

what is to be delivered preferably in cardinal point terms. This is not possible where the requirement is tacit and so not measurable. Then one has to use a hierarchical delivery system. This has to generate internal incentives for each function based on loyalty to the organization (Williamson, 1993) not a specific well defined result delivered. This is costly. It has to be expensively based on the development of teams rooted in mutual trust and tacit understanding. If this is disturbed in any way performance will be damaged in a non directly observable manner. The virtual organization is a hybrid of market and hierarchical supply. Hybrids are arguably more robust than what spawns them. However, they cannot propagate. They need the systemic separateness of their constituent partners to exist at all.

Bringing Defense Closer to the Virtual Organization

Further steps in this process of reform have been put in place and just beginning to be put in place in the UK under their Strategic Defense Review (MOD SDR 2F3/7) in the US under the Defense Reform Initiative (Cohen, 1997). Two strategies exist for the achievement of this final step. The first attempts to de-politicize the financing of development and commercial risk. The second sets out to de-bureaucratize the financing of state activity using what is called "Public Private Partnership" (PPP) in the UK This aims to allow the private sector to use its incentive systems to provide capital to satisfy military requirements in partnership with the polity. Carefully designed, such systems enable government to contract out the risks the state is not well equipped to handle eg. those of ownership, technical or commercial, while retaining those it is equipped to deal with, e.g. the political. In the limit such partnerships lead to the private sector retaining ownership of systems and so leases rather than sell them. In peace these would be directed in use by the military and maintained in a fit state by the lessor. In war the public sector would command and direct their use as well as assume the risk of loss with maintenance still perhaps in private “sponsored reserve” hands. This has the advantage of military C^2 unencumbered with non-fighting non-core consideration of the supportability and maintainability of deployed equipment. The logisticians job, whether full time professional military or outsourced sponsored reserves, is to deliver what is practicable as invisibly as possible to the fighting commander whose main effort is fighting within the constraints set by time and available material.

The second goes further. It attempts to underpin the above by introducing private sector accounting and budgeting practice into the state. The DoD originally called its approach to this Defense Business Operating Funds (DBOF) (DOD, 1995) in 1997 renamed and expanded as Working Capital Funds (WCFs) for which the SofS for Defense awarded his Hammer price for smashing costs in 1998 (DoD, 1998). This is an internal DoD regulated market set up between the front line and support functions. Military or state owned suppliers of training and maintenance compete with private sector suppliers. In the UK MoD finance staff calls this "playing shops". It makes those exercising military judgment directly accountable for the full cost of their decisions by simulating high-powered market incentives.

In the UK a more all embracing concept is proposed "Resource Accounting and Budgeting" (RAB). This makes accountable individuals aware of the full costs or their decisions by communicating it to them. By doing this it is hoped those exercising military judgment will use support functions more economically as they will have a better understanding of the impact of their decisions on the full cost of their actions. At present a commander has no incentive other than expensively generated bureaucratic direction to limit his use, or abuse, of the equipment under his command. With cost communication it is hoped behavior will change for the better.

In illustration currently spares are supplied free at the point of use. A tank engine may cost $500,000. To a commander it is free. To train a driver to use this power train less abusively has a real opportunity cost to a commander, the loss of the driver on a course. Without cost information

and outside bureaucratic regulation the commander is "better" to use tank spares at $500,000 than to train drivers at a smaller cost.

The question to be addressed here is whether communicating this cost through the hierarchy, as in the UK, or making commanders, as in the US system, directly accountable for it in a budget produces the most efficient result. Accounting alone, what the UK MoD calls the "Initial Capability" (IC) of their accounting and budgeting project only informs commanders of these full cost. Little evidence exists to show that knowing how much something costs is sufficient to alter behavior. Experience, and *a priori* analysis, suggests it will not do so without a considerable investment down through the hierarchy in staff motivation and associated organizational development. This is needed to engender the attitudes and culture required to ensure resources are used in the communal rather than individual interest. In the absence of such an incentive system or an alternate market one behavior is unlikely to change. If these two approaches de politicization and commercialization of defense accounting engender a significant cost differential between efficient and inefficient predicts ultimately they may be made effective. If this occurs they will have a profound effect on future costs and so add to the cost estimator's problems.

It is precisely because relationships between decision and cost can be vague that industry increasingly uses Activity-Based Costing (ABC) (Johnson and Kaplan, 1987). This creates a basis for optimizing incentive by developing a clear understanding of the relationship between decisions and resulting costs. Traditional absorption costing only measures the direct costs of activity, it then pro rates overheads. This is now seen as insufficient. When traditional absorption costing was conceived directly attributable costs could be as much as 80% of all costs. Nowadays many direct costs are outsourced and much remaining cost is the overhead of using communal resources, e.g. computing power, rather than cost attributable to a specific product. ABC arguably provides one with a more comprehensive understanding of cost and what drives it throughout the value chain. This enables one to highlight far better than previously accretions of cost driven by wasteful supply, production and distribution systems.

A problem then exists in managing resources internally. If the bulk of the cost of a small item produced for a particular customer is in the IT department that processes the order, organizes delivery and invoices for the service then those costs need to be allocated to the activity causing their occurrence. This is servicing the customer and not manufacturing the product. It is customer activity that drives cost, not production management. It is a lot cheaper in terms of order processing to provide a large number of parts infrequently to a customer than it is to supply a small numbers regularly. There comes a point when the cost of doing this exceeds manufacturing costs. It is this that should influence decision making not the cost of manufacture.

Thus, both the PPP and RAB have built into them incentives to contain or lower support costs.

LEAN ENTERPRISE AND THE BASIS FOR COST SAVINGS AT THE ENTERPRISE AND PROJECT LEVELS

Consideration of Commercial Best Practice in Lean Production

The modern industrial world spurred by the lowering of infrastructure costs and the possibilities of the virtual organization is moving to the "lean enterprise". This is already occurring in defense companies independent of government encouragement. This approach derives from 40 years of success in Toyota, arguably the most productive high quality car producer in the world.

Table 1

International Auto Assembly and Parts Manufacture

	TOYOTA (in Japan)	JAPAN (Average)	USA (Average)	EUROPE (Average)
Productivity (Toyota = 100)				
Assembly	100	83	65	54
1st Tier suppliers	100	83	71	62
Quality (delivered defects)				
Assembly (per 100 cars)	30	55	61	61
1st tier suppliers (ppm)	5+	193	263	1373
2nd tier suppliers (ppm)	400+	900	6100	4723
Deliveries (percent late)				
1st tier suppliers	.04+	.2	.6	1.9
2nd tier suppliers	.5+	2.6	13.4	5.4
Stocks (1st tier suppliers)				
Hours	Na	37	135	138
Stock turns (per year)	248+	81	69	45

From pp 239 Wolmack & Jones 1996

"The Machine that Changed the World"[7] describes the basis for this success:

1) Value - establish one's value proposition as seen by the final customer

2) Value Stream - identify the value stream maximizing value delivered to the customer

3) Flow - eliminate all batches, queues and re-work to establish a smooth flow from material extraction to final product

4) Pull - nothing is produced until customer demand pulls production forward.

5) Perfection – improved flow is always possible, as is increased responsiveness.

The dramatic results described have been replicated throughout the industrial world[8].

Applicability and Implementation in the Defense Environment

The most interesting application of lean production reported upon in defense is that at the Pratt & Witney Division of United Technologies. Pratt was faced with massive cutbacks in engine orders on the ending of the cold war. It was also faced with a simultaneous downturn in demand for civil aircraft engines. The results achieved in their main engine manufacturing plant are reported on in Womack and Jones (1996) as producing savings of over 50% in the cost of a turbine blade. There are 66% of tooling costs with utilized space, inventory and speed of throughput all considerably improved on the basis of a batch size that dropped from 250 to 1.

Aerospace generally provides a number of good illustration of the effects of monumental vs. lean production. The big aerospace firms separate military from civil production. They tend to have monumental production facilities financed by the state operating in a lean style for defense and lean production facilities financed by shareholders operating in a lean way for civil production. The former is designed to minimize the costs of defense department's imposed batch production. They

[7] Womack, Jones and Roos (1990)

[8] This is documented in Womack and Roos's work, "Lean Thinking" (Womack and Roos, 1996).

use specialist but expensive tools. Civil plants achieve optimality by using flow production so as to minimize tooling costs.

In defense the prior commitment of the customer, to purchasing aircraft in large batches allows the aerospace firms to calculate set-up tooling and production costs on a known production run. They then minimize production costs for the ordered batch size. They also get the government to finance any tooling costs. Their viability is conditional on this state finance of batch production.

In the civil case the number of aircraft to be built is problematic. Any estimate that can be made of a recovery rate on tooling must therefore also be problematic. Production then has to be flexible. As tooling has to be financed at the expense and risk of the shareholders civil aircraft plants are designed to minimize set-up and tooling costs.

The consequences of the above are:

1) military plants have low unit cost recovery rates on tooling relative to labor rates.

2) civil plants have high unit cost recovery rates on tooling relative to low labor rates.

Each type of plant thus has its own distinct comparative advantage. However, civil plants due to the commercial imperative of their market place tend to have an absolute advantage in both. "Dual-use" production, in the same plant, of military and civil aircraft is thus only possible at the margin. The very different capitalization rates required would otherwise results in excessive cross subsidization. In the past it has been possible to de-merge civil from military production to the absolute cost disadvantage of the latter and so the taxpayer. In doing so one has been able to add shareholder value. Cost plus defense contracts produce good low risk returns and the civil business does not have to carry any of the overheads.

However much of the enabling technologies now used in defense are "dual-use" and driven by civil commercial imperatives not defense military or political ones. As we have seen these are driving industry to global outsourcing. The economies possible using commercial infrastructure aimed at supporting everyone’s product are huge. This is the basis of the current revolution in communications, transportation and information technology. These are all “decreasing cost ” industries.(Begg, Fischer and Dornbusch, 1987) What the economic textbooks call natural monopolies i.e. the organization with the largest demand and most fully utilized capacity can out-compete all others. The result is lower and lower unit cost and faster and faster delivery. This makes it possible for everyone to confidently operate with lower inventories and outsourced supply as described earlier and facilitates the ease of creating the virtual organizations we have described and sets everything up for the lean enterprise structure of production described here. In the new global world economy inventory can be speedily acquired reliably and at low cost just in time (JIT) to fit production schedules.

Limitations as to Applicability in Defense

This approach does have its limitations even in commerce (Levy, 1997). In defense security considerations may lead to more costly solution. The advantages of lean systems can be swallowed up in costly contingent inventory or reversionary capabilities (Cusumano, 1994) if confidence does exist in speedy re-supply in case of need as is the case in defense.

In commerce firms limit the impact of such uncertainty by limiting development and production cycles to be as little as 18 months. These of course limits one to pretty modest improvements in technology from cycle to cycle but these do accumulate in a compound manner pretty quickly over a decade or so. Defense currently has a 10 to 20 year cycle. This is likely to get longer consequent to the post Cold War decline in defense industrial demand. With traditional thinking, this leads to slower, longer procurement cycles and in the absence of any obvious direct threat, contingent stocks

and in-service support are cut and or outsourced. While this is presented as consistent with "lean thinking" it is not embedded, as it is in the commercial sector, in a system ensuring responsive re-supply when required. It is to how that might be achieved in defense that we now turn.

Approaches to Overcoming Limitations

The preceding arguments make it clear that in the new age the environment for the arms industry has changed significantly.

1. There are ever-shorter product life cycles for the "dual-use" technology that defense has come to rely, on both technological and cost grounds, especially in the electronics industry
2. There are ever-longer procurement cycles for high technology weapons that increasingly incorporate commercial off the shelf (COTS) products that then need to be expensively integrated into the high technology weapons systems now in vogue.

One suggested solution to this is to evolve systems with incremental technology insertion (Cohen 1997, Ch14, Goal 1). This is a partial move from batch to flow and so lean production. However, modular insertion in a highly integrated system can be very expensive given the massive reconfiguration that may be required. Modern production techniques make it possible to consider substituting small batch more frequently purchased equipment, i.e. more flow like manufacture as a direct substitute for in-service support and maintenance.

The key to "Lean Production" is constant production rates throughout the system fuelled by increasing or at least unvarying demand. "Lean production" identifies the "takt" time, i.e. the rate at which one has to produce to satisfy demand it does not focus on minimizing the unit costs of tooling and machine time for a given batch. To use it defense has to find a way to generate steadier demand. The *a priori* cost advantages are already clear from our previous arguments.

Post Cold War warning times for military deployment are longer and arguable more controllable than in the past. In the Cold War a huge army was pre-positioned in Germany ready to fight ideally at a few weeks notice but ready to act on a shorter time scale, days or even hours. With the scenarios now being considered production rates can in theory be slowed right down when conflict is not in the offing and speeded up when a distant prospect of a deployment arises. If at the same time the equipment replacement cycle could be shortened one could then make a strong moves towards lean production. The idea would be to sustain productive capacity over time. This coupled with a shorter procurement period would enable the defense technology cycle to be brought more closely into line with developing commercial ones. Spares would then be available from production. The need to hold large stocks would go.

However, this creates logistical support problems. It would entail initially replacing older equipment at a slower but probably more affordable rate. This means having weapons of different marks in service at the same time. However this configuration problem is already reality for many weapons systems currently in service. Much of this has been retrofitted with enhancements as and when it has proved possible.

In addition modern military equipment is already becoming ever more reliant on COT's IT. This has very fast development and production timescale. When a COTS components fails it generally cannot be replaced with its like but by the latest similar COTS item designed independently of the wider system into which it needs to be integrated. Costly re-design and integration is then an inevitable cost anyway. It therefore seems sensible to build the process of doing this systematically into the structure of ones through life procurement process in a lean manner.

To achieve this one would require a cardinal points specification covering development, acquisition, utilization and disposal as the basis of all defense contracts. This would leave the commercial supplier, ideally seen as in partnership with defense, to trade-off reliability, with in-service support

with sustainability, i.e. design costs, with more frequent more costly support with costly stocks of materiel. With such a contract on offer, contractors might find it cheaper to keep production lines open working at slower rates rather than produce everything including a lifetime supply of spares and ammunition in one huge batch at the beginning of a weapons systems working life. Defense currently orders equipment and materiel in large volume over a short span of years. Spares and munitions for support and sustainment are bought up front and stored for the life of a project. Such costs are significant. So is the waste that occurs because estimates of usage prior to in-service experience are inevitably wrong. This leads to large eventually redundant stock holdings or alternatively very extensive re-contractors to replace out of stock items. A further downside is that given that the costs of running out of sustainment in combat are so high contingent over-provision is almost inevitable. Prior to the US's introduction of revolving funds and the recent capitalization of the UK MOD's accounts there was no proper means for accounting for these inventory carrying costs. The material bought, although often never used, was, under cash accounting, effectively written off on purchase and its costs as inventory never subsequently accounted for.

However the concern today is not that we may have too much but that faced with a war we may have insufficient stock to sustain a campaign. However even now using the traditional batch system one faces this prospect. Any production line will probably have been closed many years before a conflict occurs. It may then be impractical, never mind expensive, to open it up again on any useful time-scale. By the time it was possible the war might be over with lives, sovereignty or crucial interests lost.

Serious problems thus exist for both technology updating and sustainment. If manufacturing capacity is not kept in being, a problem exists for defense that needs to be addressed urgently. This cannot be solved cheaply, as seems to be currently thought by un-integrated technology insertion, re-constitution of production facility or technology demonstrators. If industry could contract to supply the availability of a military capability, this pessimistic outlook might be changeable. To achieve this we need to avoid contracting for a pre-specified platform to a specific design supplied with a huge stock of spares.

Modern warfare requires rapid deployment and high mobility with a sustainable high tempo of operations. This requires the very latest in technology. To support such a capability one might find the most cost effective way to achieve it was to sustain manufacturing capacity with smaller orders over a longer period of time. This would eliminate much of the support infrastructure now needed to sustain defense. Lean production might then seem a sensible and practical basis on which to establish defense production.

To gain the full benefits of the commercial best practice we have described defense restructuring needs to be considered systemically. Part of this is to see the defense industry as organized to provide a manufacturing capacity as a direct substitute for support. It would first have to establish demand pulled flows of value for defense products not batch pushed supply. This requires major changes in procurement, financing and military practice. If equipment management and war-fighting doctrine does not change significantly defense will not be able to access the potential cost savings we have described.

If defense manufacturing could work on a shorter cycle of flow based procurement say over 5 to 10 years rather than the current 15-20 year of batch procurement things could change dramatically. The current batch thinking requires high initial purchase costs followed by considerable inventory, updating and sustainment costs. Best modern commercial procurement involves the frequent purchase of reliable equipment requiring less in-service support. Could this be achieved in defense? Till now no one has invested the costing resources to test this hypothesis. This paper has been written to provide a theoretical basis for doing so.

Consider the UK's purchase of Apache Longbow. If the requirement could be met by building around 70 new aircraft at the rate of 10 a year every 7 years over the proposed 30 year life of the airframe would costs rise, stay the same or fall as compared to building 70 only. The latter need to be disassembled, rebuilt and upgraded throughout their life. With the former approach one creates the essential requirement for a lean system a regular flow of demand. This would allow development, tooling and set-up costs to be spread over 210 helicopters produced in a steady flow over 30 years rather than 70 in a batch produced over two or three years. As indicated above the cost benefit analysis of such an approach is yet to be done however, *a priori*, savings seem possible from lower inventory, update and support infrastructure costs. To achieve this result a partnership contract would be needed over a very long period of time. The contract would not be for the manufacture of a specified number of aircraft but for a specified number of aircraft continuously updated and serviceable on the flight line throughout the proposed lifetime of the system. The shorter production cycle we have suggested would allow evolutionary fully integrated updates to be planned on a seven year cycle producing three marks of the aircraft over its lifetime. The financial benefits of such a scheme would be enhanced if a second hand market could be created in advance for the retiring earlier marks of aircraft. The need to hold a large inventory could be eliminated perhaps. Parts would be in continuous production over the life of the system. The need for third or fourth line refurbishment could also be eliminated as new could replace old and much of the support infrastructure, of technical training staff recruitment and personnel and inventory management currently carried as an overhead by the military could be done away with.

The scenario described substitutes flow production for maintenance and sustainment stocks. This involves manufacturing at a rate that builds up a restructured inventory of equipment slowly and rotates older, or, damaged, equipment out of service to be refurbished and replaced in the line of battle with new, not refurbished equipment.

Fixed price or firm downward negotiable prices on procurement need to be the norm for this to achieve the results hypothesized. Such contracts would provide incentives for generic parts to be outsourced to industry. It discourages in-house production by eliminating the gains from cost plus.

This is conditional on the political realism of allowing commercial rates of return and underwriting long term contracts. One would have a core defense industry with a low internal cost base and a highly competitive infrastructure based on "dual use" activity.

The long term political benefits of a more fragmented, commercially based market extended in scope to cover activity currently carried out by staff either within defense departments or in primes could be considerable. These benefits would be in terms of enhanced industrial, and social, stability. People's jobs will depend on the functionality of the products or services they supply not the requirements of one particular customer, defense. A defense industrial infrastructure so freed from dependence on the vagaries of the political process clearly has utility.

Such a system of procurement would also increase the use of what Williamson has called "high powered market incentives" (Williamson, 1991). Outsourcing blurs the boundary between the firm and the market (Dietrich, 1992, Blois, 1972). In so doing it exposes generic infrastructure support providers to the risks of wider competition in the market place while leaving the political and military risks associated with conflict and contingent preparation to handle it with the state.

CONCLUSION: IMPLICATIONS FOR COST ESTIMATING

Opportunities exist to improve the public and private parts of defense provided understandable administrative, political and military cultural blocks to change can be removed. These barriers are real. If the move to value adding flow production is to be possible these need to be removed or

eased. If realistically they can only be eased rather than eliminated they will encourage rather than deliver lean production. However, the benefits to defense of the virtual organization and a cost-effective global industrial infrastructure should still lower defense costs without such radical innovations.

It is clear that no matter what, the future will radically differ from the past. New cost estimating techniques will be needed to cope with the resulting devaluation of historical databases.

If flow production is the end state then cost estimating becomes easier. In the limit all the resources to produce an item are brought together in one continuous flow production cell. This ensures that many costs are prices on inbound outsourced supplies priced by market competition. The rest are direct and observable as incurred. Cost measurement is then easier.

However cost forecasting becomes more difficult. New materials and production methods imply new cost structures. The change described intend to impact costs and performance. Given the lack of existing benchmarks new estimating techniques are needed. Among these could be synthetic manufacturing environments. Work on this, in the cost estimating sphere, has begun. NASA with GE is funding an engine costing initiative to transfer an existing piece of software, the Integrated Supportability Analysis and Cost System (ISACS) developed under UNIX, to a Windows NT/95 public domain environment (Weaks & Barrett, 1998). ISACS allows what if modeling of the impact of engine design changes on lifecycle costs. One can therefore use it to trade-off the engines rated power output against in service support costs. In the UK the lean manufacturing initiative is funding Cranfield University to develop life cycle cost estimating techniques producing composite aero-structures.

The above initiatives are all aimed at getting over the problems for estimating costs where new processes are used. Lean production is not new. It has been successful in the private sector. As we have seen Pratt and Witney have already publicly reported the effects of its use. Lean production, ironically based on old-fashioned batch thinking, is already in place in military aircraft production. But until defense gets away from the defense financed anti-lean batch mentality there is little hope of achieving the savings already achieved in civil aerospace. These changes will not occur as long as defense departments are willing to fund the cost base underpinning the old approach. The existing mentality is underpinned in aerospace by civil aerospace's losses and until recently military aerospace's profitability.

At what speed can all this be achieved? The evidence is on short time scales Womack and Jones (1996) report 30% savings inside 6 months of starting, followed by a further 35% savings inside 2 years, followed on by continuous further proportionate cost savings and productivity and quality improvements over succeeding years. Such publicly reported results have, as we have seen, been supported by experience at, at least, one US defense manufacturer, Pratt and Whitney. So it is reasonable to presume that there is no reason why they cannot be accessed generally. Clearly this will not be possible without a radical re-think of the defense enterprise seen holistically from factory to foxhole. To get demand pulling flow requires defense procurement to be spread out over time. This requires the relation between military doctrine and industrial production to be thought through very carefully indeed. The military are uncomfortable with JITs. However, it was the basis for both US and British airforce operations in World War II, i.e. to work twenty-four hours a day every day and drop ordinance on Germany at its rate of production.

A key failure of much recent defense support thinking is that it has not dealt well with sustainability. In the Cold War we operated on the basis of a short conventional war with high rates of material consumption. When stocks were exhausted we would simply use nuclear weapons. This is not realistic for the wars contemplated now. Defense departments now seem intent on having smaller stocks of smarter more expensive weapons. With current batch thinking these can not be re-ordered when used in less than five years. This does not compute militarily. What happens when your stock

of smart weapons is exhausted and the enemy is not defeated? For this reason alone defense needs flow thinking with shorter production, development and in service life cycles. Only then can low cost, investment and production rates be in tune with the possible rate of use of technologically advanced weapons. This requires PDS and configuration management to be more technically sophisticated than it is at the moment. With proper JITs support this is possible. This is a challenge to the cost estimator and forecaster who will then have to extrapolate from commercial experience.

The raises a second order problem for the estimator. The defense market can never replicate the competitive environment commercial companies operate in. One will have to assess the impact of a monopolistic defense industrial structure on the realizable cost savings from lean manufacturing.

It is clear the future provides a real challenge for the cost estimator. Synthetic environments will need to be part of the tool kit as will an understanding of the process of industrial change both from a production engineering and economic perspective.

References

Cohen, W. S. 1997. "*Defense Reform Initiative Report"*, DoD.

Bartlett, C. A. 1991.*"Caterpillar-Komatsu"*, Case Study from Harvard Business Review.

Begg, D. Fischer, S. and Dornbusch, R., 1987*"Economics"*, 2nd edition, McGraw Hill Book Company.

Binmore, K. And Dasgupta, P. 1991, *Economic Organizations as Games*, Palgrave.

Blois, K. J. 1972."Vertical Quasi-Integration, *Journal of Industrial Economics,* Vol. 20, 253-271.

Cusamano, M. 1997. “The Limits of Lean”, *Sloan Management Review,* Winter, 94-102.

Dietrich, M. 1992. "The Economics of Quasi-Integration", *Paper Malvern Political Economy Conference*, August.

DoD, "Defense, 1998. *Working Capital Fund Team Wins Hammer Award"*, Press Release, Dec.

Dyer, J. and Ouchi, W. 1993. “Japanese Style Partnerships: Giving Companies a Competitive Edge”, *Sloan Management Review*, Fall.

Fruin, M. 1992. “The Japanese Enterprise System: Competitive Strategies and Co-operative Structures”, Clarendon Press.

Johnson H. and Kaplan, 1987. R. “Relavance Lost – The Rise and Fall of Management Accounting”, Harvard Business School Press.

Levy, D. 1997. “Lean Production in the International Supply Chain”, *Sloan Management Review*, Winter.

McDuffle, J. P. and Helper, S. 1997. “Creating Lean Suppliers: Diffusing Lean Production Through the Supply Chain”, *California Management Review*, Vol. 39, No. 4, Summer.

MOD, Strategic Defense Review Study 2F3/7 1998. “Smart Procurement: Final Report”, Issue 1, 19 January.

Oliver, N. Delbridge, R. and Lowe, J. 1996 .“Lean Production Practices: International Comparisons in the Auto Components Industry”, British *Journal of Management*, Vol. 7, Special Issue, S29- S44, March.

Porter, M. 1980. “Competitive Strategy”, The Free Press.

Ward, A. Liker, J. Cristiano, J and Sobek, D. 1995. “The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster, *Sloan Management Revue*, Spring.

Weaks, C. & Barrett, D., 1998. *"The Use of Synthetic Environments in Cost Estimating",* paper Conference of the International Society for Parametric Analysis, Toronto.

Womack, J. P & Jones, D. T. 1996. *Lean Thinking,* Simon and Schuster, New York.

Womack, J. P, Jones, D. T. & Roos D. 1990. *The Machine that Changed the World”,* Simon and Schuster, Maxwell MacMillan International, Oxford.

Williamson, O. 1975. *Markets and Hierarchies: Analysis and Antitrust Implications*. New York, Free Press.

Williamson, O. 1985, *The Economic Institutions of Capitalism,* Free Ideas, New York.

Williamson, O. 1991. “Comparative Economic Organisations: The Analysis of Discrete Structural Alternatives”, *Administrative Science Quarterly,* Vol. 36, 269-296, June.

Click here to view PowerPoint presentation; Press Esc to exit

Innovations and Improvements in Cost Information Management

David M. Robinson, CDFM
Lieutenant Colonel, U.S. Marine Corps
Director, Contractor Cost Data Reporting Project Office
1800 Defense Pentagon, Room BE779
Washington, DC 20301-1800
USA

This presentation outlines the status of weapon system cost reporting in the U.S. Department of Defense (DoD), including an overview of DoD cost reporting history and a description of the major reengineering effort that began in the mid-1990s. In addition, it will summarize the planned expansion of the Contractor Cost Data Reporting (CCDR) system into a more comprehensive, life-cycle cost data and document retrieval tool, called the Defense Automated Cost Information Management System.

The DoD has been collecting cost data from the defense manufacturing industry since 1942, when it began purchasing large quantities of aircraft. There were a number of reports developed during the 1940s and 1950s that focused primarily on the aircraft and missile industries; however, cost collection was not done uniformly or with any industry-wide standards making comparisons of data rather difficult. Cost reporting continued to be refined during the 1960s and into the early 1970s until the DoD developed its current Contractor Cost Data Report system.

The CCDR system was a set of documents that standardized cost reporting across all defense industries and became the major source of independent cost data for DoD analysts. However, in the early 1990s, the CCDR system came under significant criticism from both the DoD Inspector General and defense industry manufacturers for being inaccessible, unreliable, and overly burdensome. In response to these criticisms the DoD created the CCDR Project Office and empowered it with three objectives: make old data available electronically over the World Wide Web; collect and distribute new data using the Internet; and, reduce the financial and administrative burden of cost reporting to the defense industry.

Examination of the existing cost reporting requirements revealed duplication of effort and unnecessary levels of detail in many of the reports. Much of the problem was addressed by using external sources for some of the data required, allowing for elimination of whole reporting formats and streamlining of others. In addition, the level of cost reporting detail was reduced to be more consistent with information already being gathered internally by industry.

Next, in order to get information about CCDRs and cost reporting into the hands of DoD analysts, a public access web site was developed which contains the latest policies, procedures, and directives, as well as on-line tutorials and software tools. In addition, electronic security of competition sensitive, proprietary cost information was of paramount concern to the defense industry. In response, the DoD developed a system that both meets industry's need for secure data submission and meets the Government's need to tightly control access to the data.

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

Currently, phase-one of the cost reporting system is complete with approximately 36,000 paper records scanned into a document database and with all new contracts requiring electronic submission of cost reports from manufacturers. These documents are accessible through the Internet to authorized Government users who have registered to use the system. The system is designed to allow full-text, content searches of the scanned images and data based on user defined criteria, greatly improving functionality for the user.

Everyone who interacts with the system must first complete a security registration process. This applies to both contractors and government users. In addition, there are two distinct hardware and software firewalls embedded in this system, with an internally operated firewall layered on top of the standard DoD firewall as a second set of protections, blocking all but authorized users from accessing the system.

Using this system, defense contractors create the reports and submit them, through the Internet over secured connections, to a data processing server where they are checked for quality. Once complete, reports are put into the database and made available to users. Authorized users follow the same secure connections to access the database search engine and retrieve the documents they need.

With the on-line system established and available to users, the CCDR Project Office continues to manage several ongoing programs. These include electronic archiving of CCDRs as they are submitted, actively collecting cost data on major acquisition programs, and ensuring quality standards are applied to reports as they are submitted. In addition, the Project Office provides training to both government and industry users of the system, and works closely with the defense industry to vet issues and concerns about cost reporting requirements.

The DoD recognized that the on-line CCDR system was a tremendous improvement in cost data availability, but that it could also be configured to deliver a whole host of other cost related information to its users as well. With that in mind, the Project Office established a new objective; to develop system capabilities to provide users with easy and relatively comprehensive access to larger quantities of cost information resources. To do this, improvements were made to both the public information web site and the secure site search capabilities. Control of some of the OSD internal cost related activities was transferred to the CCDR Project Office which is now incorporating them into the existing on-line system.

Development and integration of a new Cost Research Document Retrieval System is now complete. This second module of the CCDR system provides users simultaneous access to an expansive library of cost documents and to the CCDR data using the same search algorithm. Development has also begun on system interfaces that will allow users to access the operating and support cost systems being maintained by the individual military services.

As new capabilities are integrated into the current system, it has evolved into what is being called the Defense Automated Cost Information Management System or DACIMS. DACIMS users will be able to go to one secure location through the Internet, and, using a single search engine interface, locate and retrieve multiple types of cost data and information on a given program. Those cost related systems that are internal to OSD will be integrated into the DACIMS configuration, while other systems, which are maintained by either the military services or other DoD departments, will have electronic interfaces established with DACIMS. These interfaces will give users easy access to and the ability to retrieve data from these systems through DACIMS without actually making them an integral part of DACIMS.

The resulting DACIMS configuration will allow the DoD and the CCDR Project Office to make positive strides toward improving cost information availability within the DoD. This improvement in cost information access should in turn improve the quality of weapon system cost estimates over time.

This page has been deliberately left blank

Page intentionnellement blanche

Click here to view PowerPoint presentation; Press Esc to exit

Visibility and Management of Operating and Support Costs (VAMOSC) Management Information System

Leonard P. Cheshire
Naval Center for Cost Analysis
Nebraska Avenue Complex
4290 Mount Vernon Drive NW Suite 18200
Washington, DC 20393-5444
USA

EXECUTIVE SUMMARY

The Visibility and Management of Operating and Support Costs (VAMOSC) program is the most complete source of operating and support (O&S) cost data available to the three U.S. Military Services (Army, Navy and Air Force). Under the general VAMOSC umbrella, each of the services has developed its own system based on the OSD Cost Analysis Improvement Group (CAIG) cost element structure documented in DoD 5000.4M, entitled "DoD Cost Analysis Guidance and Procedures". The program includes the Navy's VAMOSC system, managed by the Naval Center for Cost Analysis (NCCA), the Air Force's system, known as Air Force Total Ownership Cost (AFTOC) and managed by the Air Force Cost Analysis Agency (AFCAA), and the Army's Operating and Support Management Information System (OSMIS), managed by the Cost and Economic Analysis Center (CEAC). These Service programs track the O&S costs for major weapon systems and some sub-systems using data drawn from their respective reporting organizations. Typical users of VAMOSC include estimators, financial programmers and logisticians.

All three Service systems face challenges to standardize cost elements and be able to validate these costs against financial data by appropriation. Each of the Service VAMOSC systems currently reports O&S costs in a format somewhat different from the CAIG O&S cost element structure. There is a continuing need to improve data sources to ensure that weapon system life cycle costs (LCC) are fully reported in a more timely fashion. Ideally, "real time" reporting of data is desired, but that is a very difficult goal to achieve. At present, Navy VAMOSC data is reported once a year. As enhancements and improvements are made, cost comparisons across Services will be easier as the systems, sources and coverage of the CAIG cost element structure are made more uniform.

Bearing in mind OSD's larger concern with the VAMOSC systems of all three Services, the purposes of this paper are to focus on the U.S. Navy's VAMOSC database, discuss its strengths and weaknesses and concentrate on its usefulness to the cost estimating discipline. O&S costs constitute a large proportion of the total LCC of Naval weapon systems. In a recent analysis, NCCA determined that O&S costs account for about one-third of electronic systems LCC, one-half of aircraft LCC and two-thirds of ships LCC. We have long recognized the prominence of O&S costs as a major component of total costs, but for many years the U.S. Navy concerned itself primarily with the development and production costs of weapon systems. Today, ten years after the end of the Cold War, we are placing renewed emphasis on controlling and reducing O&S costs.

In order to control and reduce O&S costs, we must have reliable data as to what those costs actually are, and some fundamental precepts of economic decision-making must be adhered to. If the Navy wished to consider decommissioning a number of ships and aircraft squadrons, the only costs relevant to such a decision would be those that will actually disappear if the platforms are taken out of service. Similarly, only those incremental costs incurred by bringing new weapons systems into the inventory are relevant to a decision to expand Naval forces. Therefore, this implies the necessity to collect actual O&S costs by weapon system, i.e., by individual ship, major ship system and aircraft type/model/series.

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

Navy VAMOSC is a web-enabled Management Information System that collects and reports U.S. Navy and U.S. Marine Corps (USMC) weapon system direct O&S costs, some indirect costs and some related non-cost data, on an annual basis. The VAMOSC system stores data collected from 125 sources. Coverage of active ships extends from FY84 through FY00, ships' systems from FY86 through FY00, aircraft from FY86 through FY00, aircraft systems from FY96 through FY00, missiles and torpedoes from FY92 through FY00 and USMC ground systems from FY98 through FY00.

The U.S. Navy's VAMOSC Management Information System is highly relevant to the theme of the NATO RTA Symposium on Cost Structure and Life Cycle Cost for Military Systems. As noted, O&S costs constitute a significant portion of life cycle costs, and VAMOSC is the only source of historical O&S costs for U.S. Navy ships, aircraft and other weapons systems. The resources devoted by the U.S. Navy towards the establishment and maintenance of an Oracle-based relational database accessible through the Internet have definitely advanced the state-of-the-art in estimating O&S costs.

VISIBILITY AND MANAGEMENT OF OPERATING AND SUPPORT COSTS (VAMOSC) MANAGEMENT INFORMATION SYSTEM

ABSTRACT

In the past, decision makers in the U.S. Navy focused largely on development and procurement costs to determine the inventory of ships, aircraft and other weapon systems to be acquired and operated. However, in recent years the cost of operating and maintaining these systems has become a primary factor in the acquisition decision-making process for determining force levels and composition of the U.S. Navy. As a result, great emphasis has been placed on the development, maintenance and availability of comprehensive databases for estimating operating and support (O&S) costs.

The Navy's Visibility and Management of Operating and Support Cost (VAMOSC) Management Information System displays O&S costs and related information (e.g., operating hours, manning) about ships, aircraft, ordnance and tracked/wheeled vehicles. This information is contained in an Oracle relational database in a hierarchical cost element structure, by fiscal year. Depending on the specific system, this database contains up to 15 years of data collected annually from about 125 different sources.

The objectives of the VAMOSC system are:

- To provide visibility of O&S costs for use in cost analysis of major defense acquisition programs and force structure alternatives in support of the Planning, Programming and Budgeting System (PPBS) process and satisfy the Congressional requirement that DoD track and report O&S costs for major acquisition programs.

- To provide visibility of critical maintenance and support costs at the subsystem level in sufficient detail to promote cost-conscious design and configuration management of new and fielded defense programs.

- To provide visibility of O&S costs so they may be managed to reduce and control program life-cycle costs.

- To improve the validity and credibility of O&S cost estimates by establishing a widely accepted database, thereby reducing the cost and time for collecting these defense program O&S costs for specific applications.

The VAMOSC database was initiated in 1975 with a mandate to collect, process and display actual historical costs by platform and weapon system; thus, primarily direct costs are included. With minor exceptions, no allocated costs or indirect costs are included. Historically, VAMOSC data were used predominantly to develop the O&S cost portion of LCC estimates for future weapon systems. Today, the VAMOSC database is

becoming an integral part of Navy efforts to understand better and reduce the Total Ownership Cost (TOC) of existing and future weapon systems. Navy VAMOSC is currently available to government and industry users by several means, but access is increasingly made directly to the Oracle relational database using a web browser software.

The purposes of this paper are to present an overview of the U.S. Navy's VAMOSC program, provide detailed information on the various databases that comprise VAMOSC, discuss current and future VAMOSC improvement efforts and demonstrate the utility of VAMOSC data in structuring cost estimating models, such as the Operating and Support Cost Analysis Model (OSCAM).

As a record of actual historical O&S costs of ships, aircraft, ordnance, and ground systems that are used for cost estimating purposes, the U.S. Navy's VAMOSC database is highly relevant to the symposium theme of "Cost Structure and Life Cycle Cost for Military Systems" and specifically relates to the Database topic.

HISTORY OF VAMOSC

For many years the U.S. Navy, like the Army and Air Force, had no system for the collection of actual O&S costs by weapons system, i.e., by individual ship, aircraft type/model/series, missile system, torpedo system or major ship and aircraft sub-system. Navy O&S costs associated with weapons systems are funded largely through the Operations and Maintenance, Navy (O&MN) and Manpower, Navy (MPN) appropriations. For a number of years in the 1960's and 1970's, the Navy developed O&S cost factors for the O&MN and MPN appropriations. Using budget data, these factors were generated through a process that identified some direct O&MN and MPN expenses to specific platforms and allocated all remaining O&MN and MPN to individual ship platforms and aircraft type/model/series as indirect costs.

The direct cost factors were somewhat useful for cost estimating, but had the disadvantage of being based on programming estimates, not actual return costs. O&S cost estimates based on indirect cost factors were not very useful for decision-making purposes, because they were allocated fixed costs. It became apparent that a database containing only direct assignable O&S costs by platform was needed.

In order to provide more useful O&S cost data, in 1975 the U.S. Deputy Secretary of Defense directed the Services to collect actual weapons systems O&S costs by platform and system. This directive was implemented through the Visibility and Management of Operating and Support Costs (VAMOSC) program, the most complete source of O&S cost data available to the three U.S. Military Services (Army, Navy and Air Force). Under the general VAMOSC umbrella, each of the services has developed its own system based on the OSD Cost Analysis Improvement Group (CAIG) cost element structure documented in DoD 5000.4M, entitled "DoD Cost Analysis Guidance and Procedures". The program includes the Navy's VAMOSC system, managed by the Naval Center for Cost Analysis (NCCA), the Air Force's system, known as Air Force Total Ownership Cost (AFTOC) and managed by the Air Force Cost Analysis Agency (AFCAA), and the Army's Operating and Support Management Information System (OSMIS), managed by the Cost and Economic Analysis Center (CEAC).

From 1975 to 1992, the Navy, like the Army and Air Force, pursued its individual VAMOSC system and made its own decisions regarding the structure, financing and management of the program. During this period of time, VAMOSC was not centrally managed by the Navy, but was divided into two segments, ships and aircraft, under the Naval Sea System Command (NAVSEASYSCOM) and the Naval Air Systems Command (NAVAIRSYSCOM), respectively.

A top-level management review was undertaken in 1991, resulting in some major changes. In 1992 the Office of the Secretary of Defense for Program Analysis and Evaluation (OSD(PA&E)) assumed responsibility for VAMOSC administration of all three Services. Concurrent with this development, the Navy centralized its management of VAMOSC under the Naval Center for Cost Analysis (NCCA).

In addition to administrative and managerial changes, the top-level review also mandated certain technical and procedural changes to improve the system. To address these issues, OSD (PA&E)) and the Service VAMOSC Program Management Offices established a Functional Process Improvement Program (FPIP). To carry out specific initiatives, a VAMOSC Improvement and Enhancement Working (VIEW) Group was formed. The group primarily consists of representatives from PA&E, NCCA, the Army Cost and Economic Analysis Center (CEAC) and the Air Force Cost Analysis Agency (AFCAA). The VIEW Group's guiding principles for the FPIP and the future of VAMOSC are as follows:

> "VAMOSC will be an integrated Department-wide O&S cost collection and reporting system. VAMOSC will provide easily accessed, timely, accurate O&S metrics and cost data, both direct and indirect, down to and including components, associated to selected materiel systems, to authorized customers. VAMOSC will be an open architecture environment (e.g., data warehouse) incorporating standard data definitions and information sharing across Department activities. Data will be based on "actuals" that can be traced to specific organizations that incurred the costs. The systems will support life cycle cost (LCC) management and the Planning, Programming, Budgeting System (PPBS) process. The level of cost coverage will meet user needs."

There have been significant improvements to the VAMOSC systems of the three Services, but not all of the problems discussed earlier have been solved. The Services' systems face challenges to standardize cost elements and be able to validate these costs against financial data by appropriation. Each of the Service VAMOSC systems currently reports O&S costs in a format somewhat different from the CAIG O&S cost element structure. There is a continuing need to improve data source issues to ensure that weapon system LCC are fully reported in a more timely fashion. Ideally, "real time" reporting of data is desired, but that is a very difficult goal to achieve. At present, Navy VAMOSC data is reported once a year. As enhancements and improvements are made, cost comparisons across Services will be easier as the systems, sources and coverage of the CAIG cost element structure are made more uniform.

Efforts will continue to realize more completely the guiding principles of the VIEW Group. However, even with its known deficiencies, we can definitely state that VAMOSC is the most complete source of O&S cost data available to the three U.S. Military Services. It tracks O&S costs for major weapon systems and some sub-systems using data drawn from the Services' reporting systems. Typical users of VAMOSC include estimators, financial programmers and logisticians.

The following chronology summarizes the most important events relating to the establishment and evolution of the U.S. Navy's VAMOSC into its present status.

1975 U.S. Deputy Secretary of Defense directed Services to collect actual weapon systems O&S costs

1976 Chief of Naval Operations initiated Navy and Marine aircraft data system managed by the Naval Air Systems Command

1977 Chief of Naval Operations initiated the Navy ship data system managed by the Naval Sea Systems Command

1984 DoD established VAMOSC Steering Committee to formulate policy for the program

1988 Senate Appropriations Committee directed Services to develop VAMOSC capability

1992 Responsibility for VAMOSC executive oversight and administration assigned to OSD CAIG; management of Navy VAMOSC assigned to NCCA

1996 OSD CAIG established the VAMOSC Improvement and Enhancement Working (VIEW) Group, consisting of representatives from PA&E, NCCA, CEAC and AFCAA

1997 Navy VAMOSC moved to electronic database environment

2001 Navy VAMOSC is fully web based

VAMOSC USERS

Historically, Navy, Marine Corps, OSD and industry cost analysts used VAMOSC data predominantly to develop the O&S cost portion of LCC estimates for future weapon systems. Today, the VAMOSC database is becoming an integral part of Navy efforts to understand more completely and reduce the Total Ownership Cost (TOC) of legacy and future weapon systems. Specifically, VAMOSC is being used to develop the O&S portion of TOC baselines and to identify significant cost elements that might represent cost reduction opportunities. The VAMOSC data developed by the DoD Components are the authoritative source for reliable and consistent historical O&S cost information about major defense programs. Therefore, it is incumbent upon the Navy to make VAMOSC data as accurate as possible. VAMOSC is being used for a wide variety of applications, including cost analysis, cost research, cost modeling and simulation and defense initiatives such as the Quadrennial Defense Review. Other uses include:

- Derive and/or validate O&S costs of defense programs within the acquisition process.
- Assist in design tradeoff analyses of defense programs and subsystems.
- Assist in the development of modifications and new management techniques for controlling O&S cost for defense programs.
- Support the development of programs and budgets for both existing and future defense programs as part of the PPBS process.
- Provide a basis for, or validation of, O&S cost factors used to establish standards for cost estimating.
- Assist operations and management of DoD Component organizations at all levels.

The Navy VAMOSC database is available to government and industry users by several means. Frequent users query the Oracle relational database directly using a web browser software. There are approximately 450 users who access the database directly. Infrequent users prefer to request specific data directly from NCCA via the web site. This avenue precludes the need for the user to have a working knowledge of how the aforementioned database query software operates. Government and contractor users are typically provided different levels of VAMOSC data access, as the database contains business sensitive information. Efforts are currently underway to increase the weapon system and cost element coverage, cost element visibility, timeliness and accessibility of VAMOSC data.

VAMOSC COMPONENTS

Five major areas constitute the Navy VAMOSC database: ships, ships' systems, aviation, Marine Corps ground systems, and weapons, i.e., missiles and torpedoes. When VAMOSC was initiated in the mid-seventies, there were only two components, ships and aircraft. As user requirements grew over time, VAMOSC was expanded to incorporate the other areas now covered by the system. The following table summarizes the current content of the Oracle-based VAMOSC database. Hard copy data for ships and aircraft exist for years prior to the time shown in the table.

VAMOSC SYSTEM COVERAGE	No. of System/ Platforms	FYs
Ships (by hull)		
Active Ships	675	84-00
Naval Reserve Force (NRF)	51	89-00
Military Sealift Command (MSC)	425	93-00
Ships' Systems (entire Cost Element Structure (CES) coverage)	65	86-00
Ships' Systems (O&I level maintenance, by Equipment Identification Code (EIC))	1000s	91-00
Aviation		
Aircraft (entire CES by Type/Model/Series	172	86-00
Aircraft Subsystems (O&I level maint. by EIC)	1000s	96-00
Weapons		
Air-Launched Missiles	17	92-00
Surface-Launched Missiles	9	92-00
Torpedoes	4	92-00
U.S. Marine Corps Ground Systems	176	98-00

VAMOSC UNIVERSES

A number of different reports are generated for the VAMOSC areas shown above. These reports containing various levels and aggregation of data are referred to as "universes". A universe is a logically organized grouping of sets of data inside a larger database to help provide intuition and structure to the process of extracting data from the database. The following table lists all available universes with a brief description of each. Additional information can be obtained from the NCCA VAMOSC web site.

DESCRIPTION OF VAMOSC UNIVERSES

Ships Data and Ships Data Summary Universes	The most popular universe, Ships Data, covers both active ships and Naval Reserve Force (NRF) ships which were in commission for either the full fiscal year or for part of the fiscal year. NRF data are available on line for FY98 through FY00. There are a total of 115 cost elements, including costs for manpower, fuel, ordnance, maintenance, modernization, other support, and training. There are also 23 non-cost elements, including data on steaming hours, barrels of fuel, man-days, ship status, percent of FY, number of ships, and number of personnel.

DESCRIPTION OF VAMOSC UNIVERSES (Continued)

Aviation Type / Model / Series (ATMSR) Universe	The most popular universe for aviation data, this universe contains both cost and non-cost data for entire fleets of Navy aircraft by year. The cost element structure includes 88 data elements and can be sorted by year, major claimant, and type/model (T/M) or type/model/series (T/M/S). The costs for a fleet of aircraft would be the sum of the regular and FRS aircraft. Non-cost elements include the total number of active aircraft in inventory and the total number of flight hours flown by those aircraft. Splitting the aircraft counts and flight hours into regular aircraft and FRS aircraft provides further visibility into and information about the fleet O&S costs. Additionally, the number of aircraft and engine overhauls delivered from public aviation depots is provided to government employees. Because these activities are working capital funded, the ATMSR captures financial completions of standard depot level maintenance (SDLM) and similar airframe and engine overhaul activities.
Shipboard Systems Data Universe	This universe contains data for selected shipboard systems. Cost elements include Manpower, Fuel (if applicable), Ordnance (if applicable), Maintenance, Modernization, and Training. Non-cost data include Equipment Identification Codes (EICs), Expanded Ship Work Breakdown Structure (ESWBS) codes, Initial Operating Capability (IOC), Personnel Required per System, Navy Ammunition Logistics Codes (NALCs), and Navy Enlisted Classification (NEC) codes.
Weapons Universe	This universe contains cost and non-cost elements for Air Launched Weapons. The evolution of the Weapons System Report (WSR) has resulted in a data element structure that consists of 102 cost elements and 59 non-cost elements. This number of elements was needed to ensure data of interest to all Program Managers was captured. There is no single weapon to which all cost elements apply. To most effectively display the data elements of interest to a VAMOSC system user, the WSR was transformed into three distinct databases: Air Launched Missiles, Surface Launched Missiles and Torpedoes.
Military Sealift Command (MSC) Universe	The data shown in this universe is displayed in the Cost Analysis Improvement Group (CAIG) cost element structure. MSC ships are divided into 5 programs: the Naval Fleet Auxiliary Force, the Special Mission Support Force, Pre-positioning, Ship Introduction, and the Strategic Sealift Force. There are 26 cost elements, which include costs for mission personnel, unit-level consumption, intermediate and depot maintenance, contractor support and other sustaining support. There are also 9 non-cost elements, which include data on steaming hours underway and not underway, and number of officer and enlisted personnel.

DESCRIPTION OF VAMOSC UNIVERSES (Continued)

Detailed Ships Universe	This universe contains lower-level cost and non-cost data from FY91 through FY00 for Manpower, Fuel, Training, Ordnance, Maintenance, Modernization, and Utility elements. Data contained within the Detailed Ships Data Universe cover both active ships and Naval Reserve Force (NRF) ships which were in commission for either the full fiscal year or for part of the fiscal year. NRF data are available on line for FY98 through FY00. Partial year ship data are included in this universe beginning with FY98 data.
Aviation Maintenance Subsystem Database (AMSD)	This universe contains Operations and Support Costs as well as Maintenance information derived from AV-3M data. The data has been reported by Type Equipment Code, Type/Model, Type/Model/Series and Work Unit Code since 1996, and is categorized by Aircraft or Engine. An engineering effort to design a new universe that capitalizes on AV-3M data was recently completed.
USMC Ground Equipment Universe	This universe displays O&S cost and related data on major ground combat systems by fiscal year. The ground combat systems universe includes trucks, howitzers, assault amphibious vehicles, light armored vehicles and tanks. The universe contains maintenance labor hours and parts costs from organizational and intermediate level maintenance for each ground system.

VAMOSC COST ELEMENT STRUCTURES (CES)

Navy VAMOSC provides two reporting formats, or Cost Element Structures (CESs), for cost data. One of the formats follows the OSD CAIG definitions delineated in the OSD CAIG Operating and Support Cost-Estimating Guide, May 1992, at a fairly high level of aggregation, while the other provides more detailed information at a lower level. The Navy has been tasked to report cost data in conformance with CESs and definitions for specific categories of weapon systems. These cost elements are used in the development of life cycle cost estimates and in the presentation of all acquisition program reviews to the Defense Acquisition Board. The 125 data providers report VAMOSC data in the various formats in which they collect the data. When the Services' VAMOSC systems were established in the mid-seventies, one of the ground rules was that no new data reporting systems could be required: activities were to report data according to the collection systems they already had in place. Thus, efforts to improve VAMOSC data collection and make it a more useful cost estimating tool have always had to deal with this constraint. Therefore, we cannot simply require that all reporting activities report data in a format consistent with the OSD CAIG Cost Element Structure.

The following chart reflects the VAMOSC ships' CES according to the structure in which the Navy collects cost and other information from our data providers. The chart after that displays the CAIG CES. As can be readily observed, the VAMOSC CES contains more details, while the CAIG CES prescribes a higher, more aggregated level of detail. We are able to make a reasonably accurate cross mapping of the VAMOSC CES into the CAIG format.

VAMOSC SHIPS DATA COST ELEMENT STRUCTURE (CES)	
CES	**DESCRIPTION**
1	**DIRECT UNIT COST**
1.1	PERSONNEL
1.1.1	MANPOWER
1.1.1.1	MANPOWER-NAVY
1.1.1.1.1	OFFICER MANPOWER-NAVY
1.1.1.1.2	ENLISTED MANPOWER -NAVY
1.1.1.2	MANPOWER-MARINE
1.1.1.2.1	OFFICER MANPOWER - MARINE
1.1.1.2.2	ENLISTED MANPOWER - MARINE
1.1.2	PERMANENT CHANGE OF STATION (PCS)
1.1.3	TEMPORARY ADDITIONAL DUTY (TAD)
1.2	MATERIAL
1.2.1	SHIP PETROLEUM, OIL AND LUBRICANTS (POL)
1.2.1.1	PETROLEUM, OIL AND LUBRICANTS (PROPULSION AND SHIPS SERVICES)
1.2.1.1.1	FUEL UNDERWAY (no longer used)
1.2.1.1.2	FUEL NOT UNDERWAY (no longer used)
1.2.1.2	OTHER PETROLEUM, OIL AND LUBRICANTS (POL)
1.2.2	REPAIR PARTS/REPAIRABLES
1.2.3	SUPPLIES
1.2.3.1	EQUIPMENT/EQUIPAGE
1.2.3.2	CONSUMABLES
1.2.4	TRAINING EXPENDABLE STORES
1.2.4.1	AMMUNITION
1.2.4.2	OTHER EXPENDABLES
1.3	PURCHASED SERVICES
1.3.1	PRINTING AND REPRODUCTION
1.3.2	ADP RENTAL AND CONTRACT SERVICES
1.3.3	RENT AND UTILITIES
1.3.4	COMMUNICATIONS
2	**DIRECT INTERMEDIATE MAINTENANCE**
2.1	AFLOAT MAINTENANCE LABOR
2.2	ASHORE MAINTENANCE LABOR
2.3	MATERIAL (DIM)
2.3.1	AFLOAT REPAIR PARTS
2.3.2	ASHORE REPAIR PARTS
2.4	COMMERCIAL INDUSTRIAL SERVICES

VAMOSC SHIPS DATA COST ELEMENT STRUCTURE (CES)	
WBS	**DESCRIPTION**
3	**DIRECT DEPOT MAINTENANCE/MODERNIZATION**
3.1	SCHEDULED SHIP OVERHAUL
3.1.1	REGULAR OVERHAUL
3.1.1.1	PUBLIC SHIPYARD (ROH)
3.1.1.1.1	OVERHEAD (ROH PUBLIC)*
3.1.1.1.2	LABOR (ROH PUBLIC)*
3.1.1.1.3	MATERIAL (ROH PUBLIC)*
3.1.1.2	PRIVATE SHIPYARD (ROH)
3.1.1.3	SHIP REPAIR FACILITY (ROH)
3.1.1.3.1	OVERHEAD (ROH SRF)*
3.1.1.3.2	LABOR (ROH SRF)*
3.1.1.3.3	MATERIAL (ROH SRF)*
3.1.2	SELECTED RESTRICTED AVAILABILITY (SRA)
3.1.2.1	PUBLIC SHIPYARD (SRA)
3.1.2.1.1	OVERHEAD (SRA PUBLIC)*
3.1.2.1.2	LABOR (SRA PUBLIC)*
3.1.2.1.3	MATERIAL (SRA PUBLIC)*
3.1.2.2	PRIVATE SHIPYARD (SRA)
3.1.2.3	SHIP REPAIR FACILITY (SRA)
3.1.2.3.1	OVERHEAD (SRA SRF)*
3.1.2.3.2	LABOR (SRA SRF)*
3.1.2.3.3	MATERIAL (SRA SRF)*
3.1.3	OTHER SCHEDULED SHIP OVERHAUL
3.2	NONSCHEDULED SHIP REPAIRS
3.2.1	RESTRICTED AVAILABILITY
3.2.1.1	PUBLIC SHIPYARD (RAV)
3.2.1.1.1	OVERHEAD (RAV PUBLIC)*
3.2.1.1.2	LABOR (RAV PUBLIC)*
3.2.1.1.3	MATERIAL (RAV PUBLIC)*
3.2.1.2	PRIVATE SHIPYARD (RAV)
3.2.1.3	SHIP REPAIR FACILITY (RAV)
3.2.1.3.1	OVERHEAD (RAV SRF)*
3.2.1.3.2	LABOR (RAV SRF)*
3.2.1.3.3	MATERIAL (RAV SRF)*
3.2.2	TECHNICAL AVAILABILITY (TAV)
3.2.2.1	PUBLIC SHIPYARD (TAV)
3.2.2.1.1	OVERHEAD (TAV PUBLIC)*
3.2.2.1.2	LABOR (TAV PUBLIC)*
3.2.2.1.3	MATERIAL (TAV PUBLIC)*
3.2.2.2	PRIVATE SHIPYARD (TAV)

VAMOSC SHIPS DATA COST ELEMENT STRUCTURE (CES)	
WBS	**DESCRIPTION**
3.2.2.3	SHIP REPAIR FACILITY (TAV)
3.2.2.3.1	OVERHEAD (TAV SRF)*
3.2.2.3.2	LABOR (TAV SRF)*
3.2.2.3.3	MATERIAL (TAV SRF)*
3.2.3	OTHER NON-SCHEDULED SHIP REPAIRS
3.3	FLEET MODERNIZATION
3.3.1	PUBLIC SHIPYARD (FM)
3.3.1.1	OVERHEAD (FM PUBLIC)*
3.3.1.2	LABOR (FM PUBLIC)*
3.3.1.3	MATERIAL (FM PUBLIC)*
3.3.2	PRIVATE SHIPYARD (FM)
3.3.3	SHIP REPAIR FACILITY (FM)
3.3.3.1	OVERHEAD (FM SRF)*
3.3.3.2	LABOR (FM SRF)*
3.3.3.3	MATERIAL (FM SRF)*
3.3.4	CENTRALLY-PROVIDED MATERIAL
3.3.5	OTHER (FM)
3.3.6	OUTFITTING AND SPARES
3.4	OTHER DEPOT
3.4.1	NAVAL AVIATION DEPOT (NADEP)
3.4.1.1	OVERHEAD (NADEP)*
3.4.1.2	LABOR (NADEP)*
3.4.1.3	MATERIAL (NADEP)*
3.4.2	FIELD CHANGE INSTALLATION
3.4.3	REWORK
3.4.3.1	ORDNANCE REWORK
3.4.3.2	HULL, MECHANICAL AND ELECTRICAL REWORK (HME)
3.4.3.3	ELECTRONIC REWORK
3.4.4	DESIGN SERVICES ALLOCATION
3.4.5	PERA, SUBMEPP PLANNING AND PROCUREMENT
3.4.5.1	PERA, SUBMEPP PLANNING
3.4.5.2	PERA, SUBMEPP PROCUREMENT
3.4.6	SHIP PROGRAM MANAGER (SPM)
4	**OTHER OPERATING AND SUPPORT**
4.1	TRAINING
4.2	PUBLICATIONS
4.3	ENGINEERING AND TECHNICAL SERVICE (ETS)
4.4 **5**	AMMUNITION HANDLING **TOTAL**

VAMOSC SHIPS NON-COST ELEMENT STRUCTURE (CES)	
A	**SHIP OPERATING DATA**
A.1	NUMBER OF SHIPS
A.2	PERCENT OF FY
A.3	NUMBER OF ENLISTED PERSONNEL
A.3.1	NUMBER OF ENLISTED PERSONNEL - MARINE
A.3.2	NUMBER OF ENLISTED PERSONNEL - NAVY
A.4	NUMBER OF OFFICER PERSONNEL
A.4.1	NUMBER OF OFFICER PERSONNEL - MARINE
A.4.2	NUMBER OF OFFICER PERSONNEL - NAVY
A.5	STEAMING HOURS
A.5.1	STEAMING HOURS UNDERWAY
A.5.2	STEAMING HOURS NOT UNDERWAY
A.6	TOTALS BARRELS OF FUEL CONSUMED
A.6.1	BARRELS OF FUEL CONSUMED UNDERWAY
A.6.2	BARRELS OF FUEL CONSUMED NOT UNDERWAY
A.6.3	BARRELS OF FUEL CONSUMED OTHER
B	**SHIP MAINTENANCE DATA**
B.1	O-LEVEL REPORTED MAINTENANCE LABOR MANHOURS
B.2	I-LEVEL MAINTENANCE LABOR MANHOURS
B.2.1	I-LEVEL AFLOAT MAINTENANCE LABOR MANHOURS
B.2.2	I-LEVEL ASHORE MAINTENANCE LABOR MANHOURS
B.3	MANDAYS (ROH PUBLIC)*
B.4	MANDAYS (SRA PUBLIC)*
B.5	MANDAYS (RAV PUBLIC)*
B.6	MANDAYS (TAV PUBLIC)*
B.7	MANDAYS (FM PUBLIC)*

*BUSINESS SENSITIVE DATA

OSD CAIG SHIPS DATA COST ELEMENT STRUCTURES (CES)	
Element No.	**Description**
1	**Mission Personnel**
1.1	Ship Personnel
1.1.1	Officer
1.1.2	Enlisted
2	**Unit Level Consumption**
2.1	Ship POL
2.1.1	Fuel (FOSSIL)
2.1.2	Other POL
2.2	Repair Parts/Supplies
2.3	Depot-Level Repairables
2.4	Training Munitions/Expendable Stores
2.5	Purchased Services
2.6	Other (TAD)
3	**Intermediate Maintenance**
3.1	Maintenance Afloat
3.2	Maintenance Ashore
3.3	Repair Parts/Supplies
3.4	Commercial Industrial Services
4	**Depot Maintenance**
4.1	Scheduled Overhaul
4.2	Nonscheduled Overhaul
4.3	Fleet Modernization
4.4	Equipment Rework
4.5	Naval Aviation Depot
4.6	Other Depot
5	**Contractor Support**
6	**Sustaining Support**
6.1	Support Equipment Replacement
6.2	Centrally Provided Material
6.3	Sustaining Engineering Support
6.4	Software Maintenance Support
6.5	Simulator Operations
6.6	Other
7	**Indirect Support**
7.1	Personnel Support
7.2	Installation Support

ONGOING ENHANCEMENTS AND IMPROVEMENTS

In 1999, NCCA hired an independent contractor to conduct a thorough Independent Validation and Verification (IV&V) effort of Navy VAMOSC, which was completed in February 2000. We identified 85 enhancements and improvements that needed to be accomplished in order for VAMOSC to provide the full range of capability needed by our users. Many of these enhancements and improvements involved information technology (IT) advancements, while others addressed expanded data coverage, improved processing and display of data and managerial improvements. All but five of the recommended enhancements and improvements have been accomplished to date. The uncompleted items are receiving priority attention to ensure their complete and timely implementation.

FUTURE GOALS AND IMPROVEMENTS

NCCA has a number of initiatives planned for the future, most of them involving technical redesign of portions of the system, while others focus on addressing more detailed coverage desired by some of our users. The redesign goals will result in dynamic escalation of constant year dollars, dynamic rollups of base elements for enhancing the ease of future database updates, and separating costs and count elements to allow vertical math on the database. At present, a change made to an element in one of our database universes does not automatically correct all subsequent information that uses that element. The dynamic escalation and dynamic rollup improvements will largely correct this problem. NCCA will have these important modifications implemented by the end of this year.

Additional expansion of the database itself will also be undertaken. For example, we want to have increased depth and precision in organizational and intermediate maintenance and military personnel costs. Different types of fuel experience different price increases, so we plan to develop and apply different inflation rates to different types of fuel. We also plan to add other metrics to the database, such as the amount of fuel consumption in gallons and the number of personnel actually assigned to operational units.

Redesign specifications will be implemented in some of the database universes. The Aircraft Type-Model-Series Report will identify Navy and Marine Corps personnel by function, i.e., operations, maintenance or support. Details of actual payroll (base pay, allowances, bonuses, Federal Insurance Contribution Act (FICA) and retirement accrual) will be displayed by function. Summary level payroll costs will also be shown; for example, in addition to the details of payroll, all components of pay will be shown in a single element as well.

Redesign specifications for the Ships System Universe will involve improvements to the historical data, structural and quality components of the database. With respect to historical data, there will be standardization, updating and correction of past data, based on updated source data. In the area of structural changes, there will be standardization of CESs, modification of the cross mapping between the VAMOSC and CAIG CESs and more details in the Individual Ships Report. Quality improvements will include addressing the remaining incomplete enhancements and improvements identified in the IV&V process, and strengthening intermediate level maintenance by capturing and screening all costs.

SUMMARY

Although NCCA has made significant improvements in Navy VAMOSC in recent years, we see this as a continuing process. Recognizing that needs may change over time, we will continue to ask our users for feedback regarding Navy VAMOSC, and will exert every effort to accommodate their recommendations and suggestions. Importantly, NCCA will stay abreast of ever-changing Information Technology advances and take full advantage of the latest technical innovations.

References:

1. Visibility and Management of Operations (sic) and Support Cost (VAMOSC), Functional Process Improvement, Phase 2, Data Model Report, January 1998

Click here to view PowerPoint presentation; Press Esc to exit

OSCAM – Simulating Operation and Support Costs Using System Dynamics

Julian Burridge
SPS/Cost Forecasting
Elm1b #187
Ministry of Defence
Abbey Wood
Bristol, BS34 8JH
United Kingdom

Jonathan Coyle
HVR Consulting Services Ltd
Selborne House
Mill Lane
Alton
Hants, GU34 2QJ
United Kingdom

SPS is one of the primary sponsors for OSCAM development and support in the UK MoD. HVR Consulting Services Ltd (HVR) is the developer of the software on behalf of MoD and DoD.

BACKGROUND

1. In the spring of 1996 the UK Ministry of Defence (MoD) Specialist Procurement Services, now part of the Defence Procurement Agency and US Department of Defense (DoD) representatives discussed the need for a new cost model for the Operation and Support elements of an equipment life cycle. Concerns had been expressed that existing tools did not properly represent the dynamic nature of Operation and Support (O&S), nor were they tailored to the needs of users. Therefore in August 1996 a contract to develop a 'proof of concept' demonstrator for shipboard systems (Sys model) was placed with HVR-CSL. This demonstrator was delivered in late 1996 and became known as the Operation and Support Cost Analysis Model (OSCAM).

2. Pretty early on it was recognised that OSCAM Ship and Ship Sys models were particularly useful to HILS(N), now part of the UK Warship Support Agency Whole Life Support Group. As a result work on these models has been jointly funded with SPS in the UK.

3. Following the success of the Sys demonstrator, version 1.0 of a Sys model and a separate Ship model were both delivered in late 1997. Since then, there have been several versions of the OSCAM Sys and Ship models (version 5.0 was released in June 2001) and other models have been developed. These other models include OSCAM Land, OSCAM ADGE, and OSCAM FASH in the UK, as well as OSCAM AAAV and OSCAM Air in the US.

WHY CONCENTRATE ON O&S COSTS?

4. The end of the Cold War witnessed the demise of the main defence threat to the West. This led to smaller defence budgets and enabled Governments to spend the monies saved on other priorities (health, education etc.) and reduce personal taxation. Collectively this was known as the 'peace dividend'. Shrinking budgets generally means one of two things: 1) you try to achieve the same outputs with less money, i.e. greater efficiency; or 2) you reduce your outputs to match with your inputs. The intelligent money went on the first of these two options.

5. One obvious place to make savings was from the operation and support phases of an equipment life cycle as this is where the majority of the life cycle costs are expended. Ships and ship systems are a particular challenge given the refitting and maintenance cycles. At the same time, the US DoD were fortunate in having a large database called VAMOSC which could be used to populate and test models. This led to a joint project in which the UK funded OSCAM shipboard sys(tem) and ship model development and the US provided data. The success of these programmes resulted in a jointly funded development programme with Ship and Sys costs shared between the US and UK. Each country has now funded further models to tackle particular equipment types.

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

METHODOLOGY FOR DEVELOPING AN OSCAM TOOL

6. The OSCAM model tool set is based on the concept of System Dynamics modelling. This technique enables the processes surrounding operating and maintaining the equipment to be mapped into the model.

7. To develop the model(s) takes time, commitment and resources from the developers, sponsors, and stakeholders who operate and support the equipment. The initial stage is a facilitated workshop. During this session, all processes are identified and mapped out. Further workshop sessions then take place on each process. The end result is an influence diagram of all maintenance and support activities that make up the system dynamics model. Near neighbour or reference systems can then be used to initially populate the model. Forecasts for new systems or equipment O&S costs can then be soundly based.

ADDITIONAL (BUT RELATED) TOOLS

8. The DMT (Data Management Tool) was developed so that platforms and equipment could be modelled in more detail. Whilst OSCAM works at a fairly high level to represent platforms or whole equipment, many users are interested in identifying which pieces of a system are the 'cost drivers'. As a result DMT was developed so that it can be used in isolation or 'fed into' OSCAM to produce O&S costs.

9. The PCT (Parametric Cost Tool) has been developed to enable analysis of data such that trends can be identified.

OSCAM SHIP AND SYS (UK AND US)

10. After a recent Validation and Verification exercise, OSCAM Ship and Sys(tem) models are now both considered fully mature. As a consequence they have moved from the development to upkeep phase. The release of version 5.1 is imminent, however version 6.0 has been put on hold awaiting developments.

11. OSCAM Ship and Sys are being used on several platforms such as Type 23 and CV(F), in addition OSCAM Sys is planned to be used on the Sonar & Signature Improvement Programme. In addition the benefits of Reliability Centred Maintenance was addressed using OSCAM for the Hunt class of vessels.

OSCAM LAND (UK)

12. The development of UK OSCAM Land over the last two years culminated in the release of Version 4.03 in August 2001. The OSCAM Land model has undergone a successful Verification and Validation exercise and is being used on a myriad of 'land' projects including the Terrier programme. Terrier is the programme for replacing the ageing Combat Engineer Tractor (CET).

OSCAM ADGE (UK)

13. A model was developed for the Air Defence Ground Equipment by RAF HQ. Version 1.0 was released in 1999.

OSCAM FASH (UK)

14. A model was developed for the Future Amphibious Support Helicopter (FASH) IPT - now SABR IPT. V1.0 of this model was V&V'd and the intention was to upgrade this to V2.0. However due to a change in priorities on the project this has not yet been progressed.

15. As the FASH model was based on Sea King data there now exists the basis for a model for rotary wing naval aircraft.

UK OSCAM AIR (UK)

16. Due to the difficulties associated with Air projects across the Services, this has been put on hold. Whereas the Navy currently operates a 'three trade' maintenance system, the RAF uses five. The Navy generally maintains their aircraft on a chronological basis, whereas the RAF operates on a flying hour based routine. These issues are currently being addressed under the heading of Joint Force 2000. Add into the equation the way that the army do their aircraft maintenance and there are challenging issues to be addressed before developing a generic air model such as OSCAM, that is based on system dynamics modelling of current support methods. Further work is needed before deciding if a generic 'Air' model is useful or whether a range of separate models would be required. This needs to be resolved as it impacts budgets.

US DoD MODELS

17. In addition to making extensive use of the Ship and Sys models, the US DoD have developed bespoke models for their own use such as OSCAM AAAV and OSCAM Air (C17).

SUPPORT (INCLUDING TRAINING)

18. Support to existing models is seen as key to ensuring that the initial investment is not wasted. Therefore SPS have placed a contract that covers, amongst other things, the development of training packs, the provision of courses, help desk and change control.

19. Current courses range from 1 day 'awareness' to 5 day detailed 'expert' courses on OSCAM Ship and Ship Sys. Both internal to MoD and Industry can, and have, attended these courses.

MODEL DEVELOPMENT

20. As stated earlier, OSCAM has been developed using a methodology known as System Dynamics (SD). This approach was developed in the late 1950s at MIT and was one of the first dynamic business process modelling techniques. It was chosen for OSCAM for the following reasons:

- SD is a well established approach and so this reduced the project risk;
- We wanted to be able to study alternative support and maintenance strategies and so needed a business process model; and
- Use of a dynamic, time based simulation technique creates a more accurate representation of the operating conditions of the equipment which is one of the primary drivers of O&S costs.

21. A primary part of the SD methodology is the use of diagrammatic techniques to develop a representation of how the system under study works. In this case, this was achieved by breaking the problem into sectors and developing an "influence diagram" (ID) for each one. An example of a simplified ID can be seen at Figure 1 below:

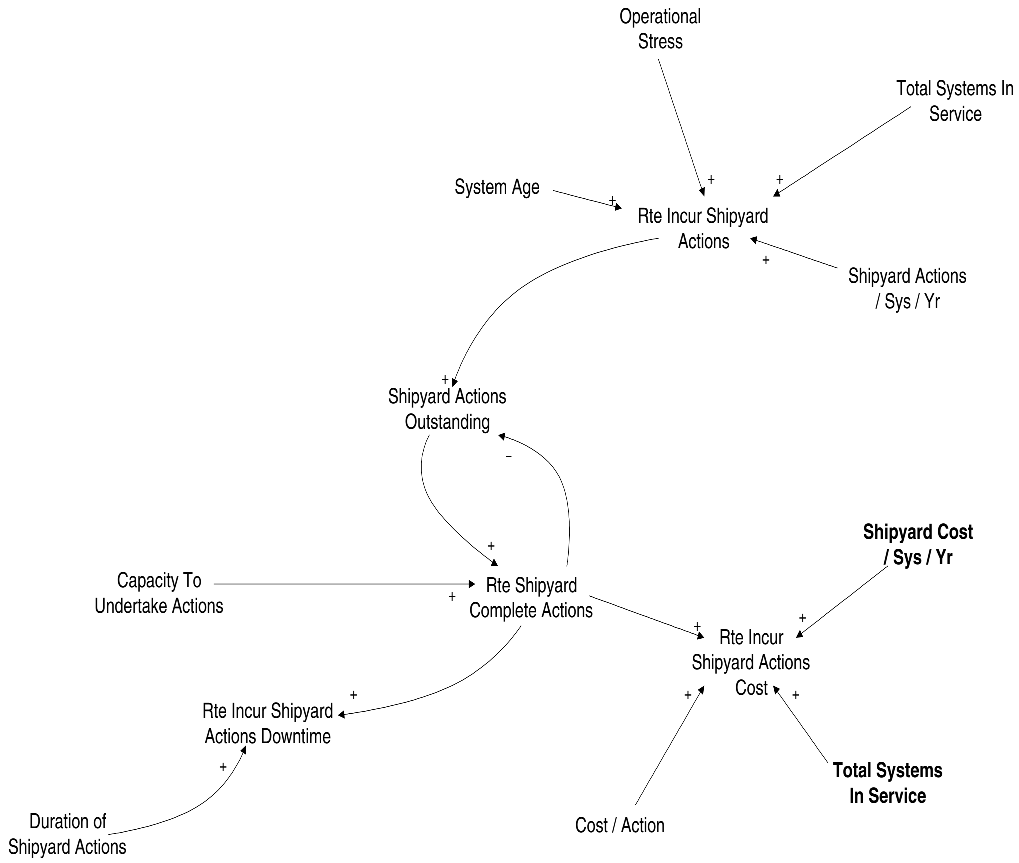


Figure 1. Example Influence Diagram.

22. IDs break the problem down into variables such as "shipyard actions outstanding" and link them to related variables with arrows that point in the direction of the relationship. Thus, in figure 1 "rte incur shipyard actions" directly affects "shipyard actions outstanding". Clearly, an increase in the former will have the same effect on the latter, so a plus sign is attached to the arrow to illustrate this. If the effect were the obverse, a minus sign would be used. The real beauty of these diagrams lies in two benefits:

- There is no particular syntax or grammar associated with them which allows the diagram to be presented to the user in his own language. This enables the user to understand the diagram rapidly and contribute his own knowledge to the development of it. In the case of all the OSCAM models, the user has been involved throughout the development process which greatly enhances their validity: and
- The diagrams allow cause and effect to be traced enabling complex interactions to be shown in a clear and simple way. This greatly facilitates the process of diagnosing model behaviour and ensures that OSCAM is not a "black box".

23. A set of IDs, known as sectors, are linked together to form a representation of the entire O&S process. The sectors that make up OSCAM (Ship) can be seen at Figure 2 below:

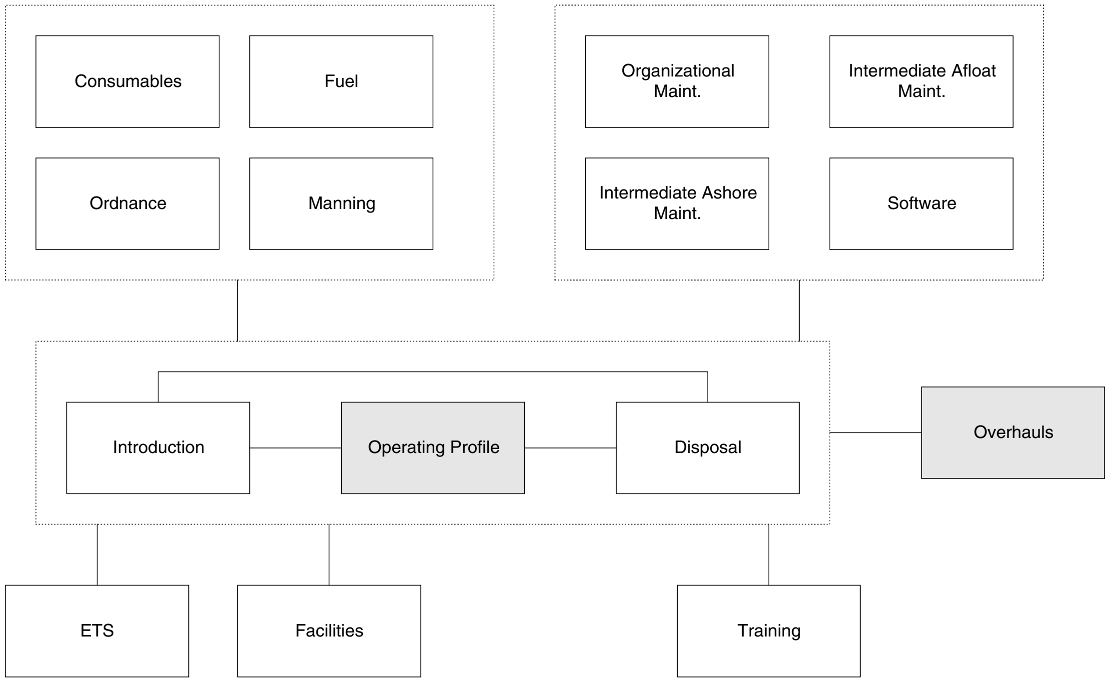


Figure 2. Sectors of OSCAM (Ship).

24. In Figure 2, the spine of the model is represented by the three sectors in the middle known as "introduction", "operating profile", and "disposal". These represent the life cycle of the equipment and, in most models, the middle section is split into a number of environments. This allows us to distinguish between equipment used for, say, training and those used on real operations. The beauty of this is that different operating conditions and their associated stresses can be represented providing an accurate representation of real operations and their impact on the equipment. Around this spine, are sectors that deal with the various lines of maintenance, consumables of various types, other facilities, and, in particular the overhaul cycle of the equipment. Each of these can be varied or bypassed. This allows us to simulate a wide variety of alternative maintenance strategies such as Reliability Centred Maintenance (RCM) or Contractor Logistic Support (CLS). For example, to simulate RCM, the user would build up his scenario by varying one parameter at a time. He might start by reducing the number of repairs at first line being the anticipated benefit of this policy. Clearly, this would produce a beneficial result at the end of the model run, so he would now want to consider the penalty that needs to be paid to achieve this result. This could be represented by increasing the number of inspections that were needed at first line or by investing in test equipment. By slowly building up this scenario in this way, the user would be able to assess the pros and cons of a particular policy initiative.

THE SIMULATION APPROACH

25. OSCAM is a deterministic time based simulation. This approach is illustrated at figure 3 below:

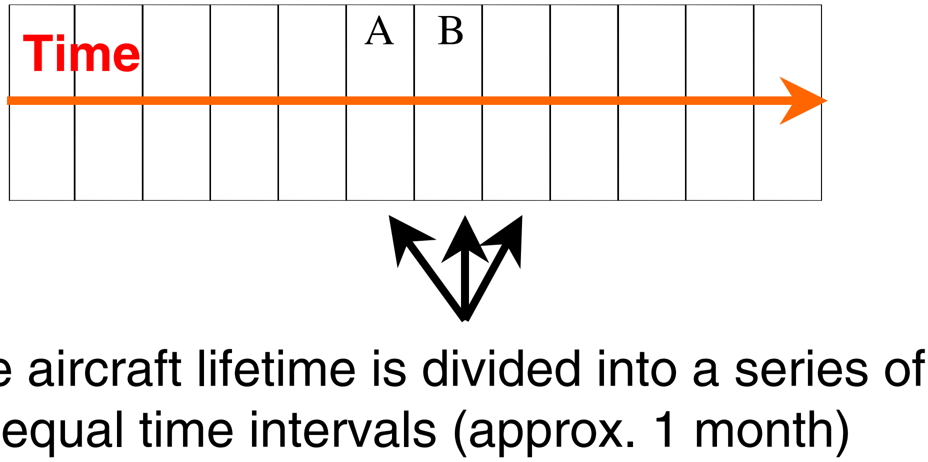


Figure 3. Simulation Process

26. Figure 3 shows that we take the lifetime of the equipment and divide these into a number of constant time intervals. The status of the equipment is calculated based on its status in a previous time point plus or minus any factors that may have affected it in that period. Thus, in figure 3, the status if the equipment at time point B is what it was at A plus or minus all the other calculations carried out during period B. This means that, as the equipment moves down the arrow in figure 3, its status increasingly becomes one of calculation by the model rather than of initial assumption. This allows us, for example, to insert shocks into the system and create a more accurate representation of the lifecycle of the equipment. One of the primary benefits of this is that it minimises the data sets needed to run the model.

SOFTWARE ARCHITECTURE

27. OSCAM was developed using a SD case tool known as Powersim. This is a very powerful piece of software but is not particularly user friendly. We therefore developed a shell that sits around the model, written in a language known as Delphi. This makes the model much more accessible and gives it a Microsoft Office look and feel. The benefit of this is that users can get to grips with the model quickly and that training can focus on the detailed calculations of the tool rather than user access. An example of an OSCAM screen can be seen at Figure 4 below.

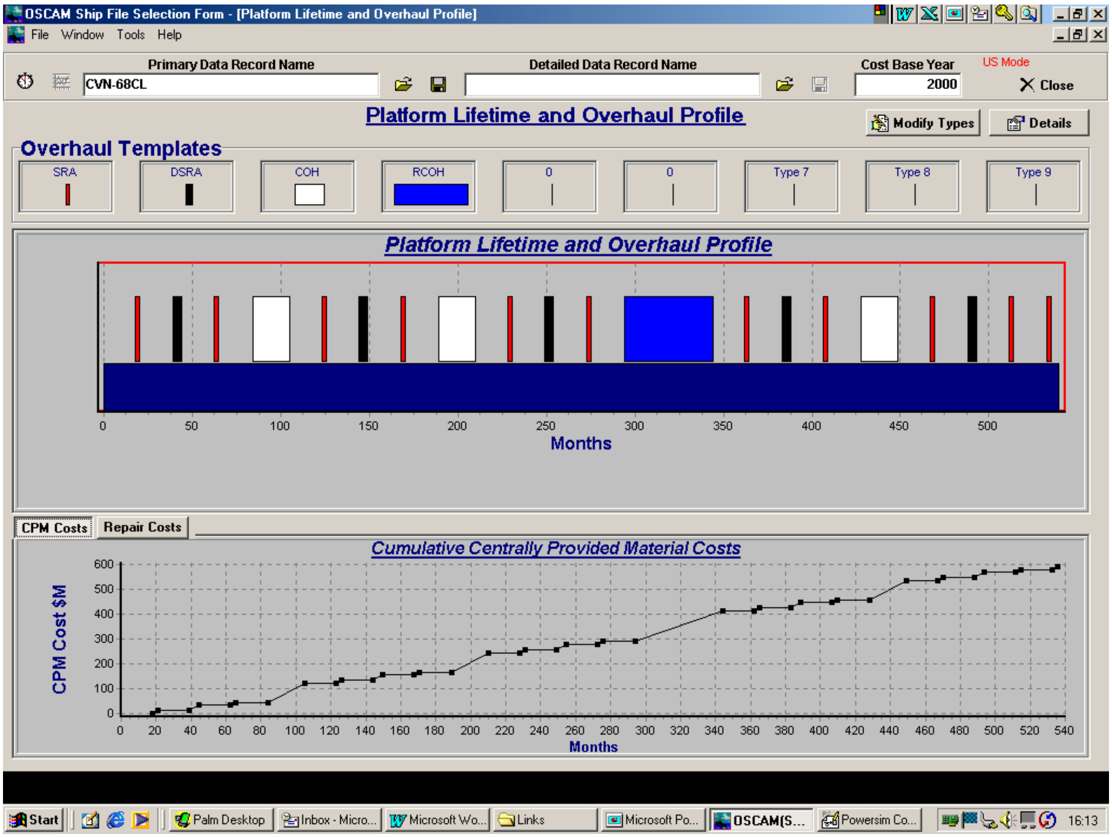


Figure 4. Example OSCAM Screen

28. Data is stored in ACCESS databases that are obviously compatible with other tools such as Excel of other SQL databases. This greatly facilitates the collection as well as the storage of data. However, OSCAM does require fairly aggregated data to drive it. This is not always readily accessible and so we created a second tool know as the Data Management Tool (DMT). This enables the user to create any kind of hierarchy that he likes, enter data at the lowest level and aggregate it up to provide an OSCAM compliant data set. An example can be seen at Figure 5 below.

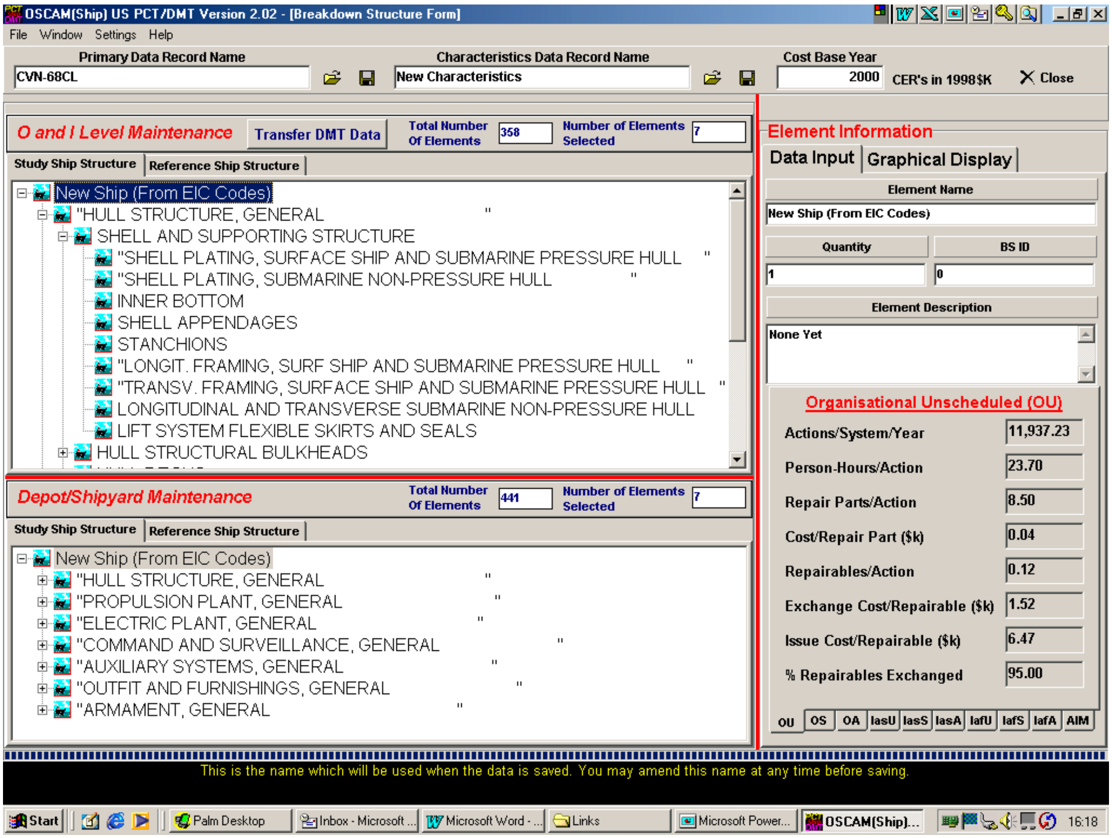


Figure 5. OSCAM DMT Screen

29. The DMT is designed to look like Windows Explorer and therefore any node that has a plus sign next to it has children. Data can only be entered at the lowest level. Any type of hierarchy can be created and the user does not have to go down to the same level of detail in all areas. This allows complete flexibility and it should be possible to create an OSCAM data set from almost any source.

30. OSCAM models can be run in a few seconds on a standard PC. This allows us to offer a wide range of analytical capabilities such as uncertainty and sensitivity testing. An example of a sensitivity screen can be seen at figure 6 below:

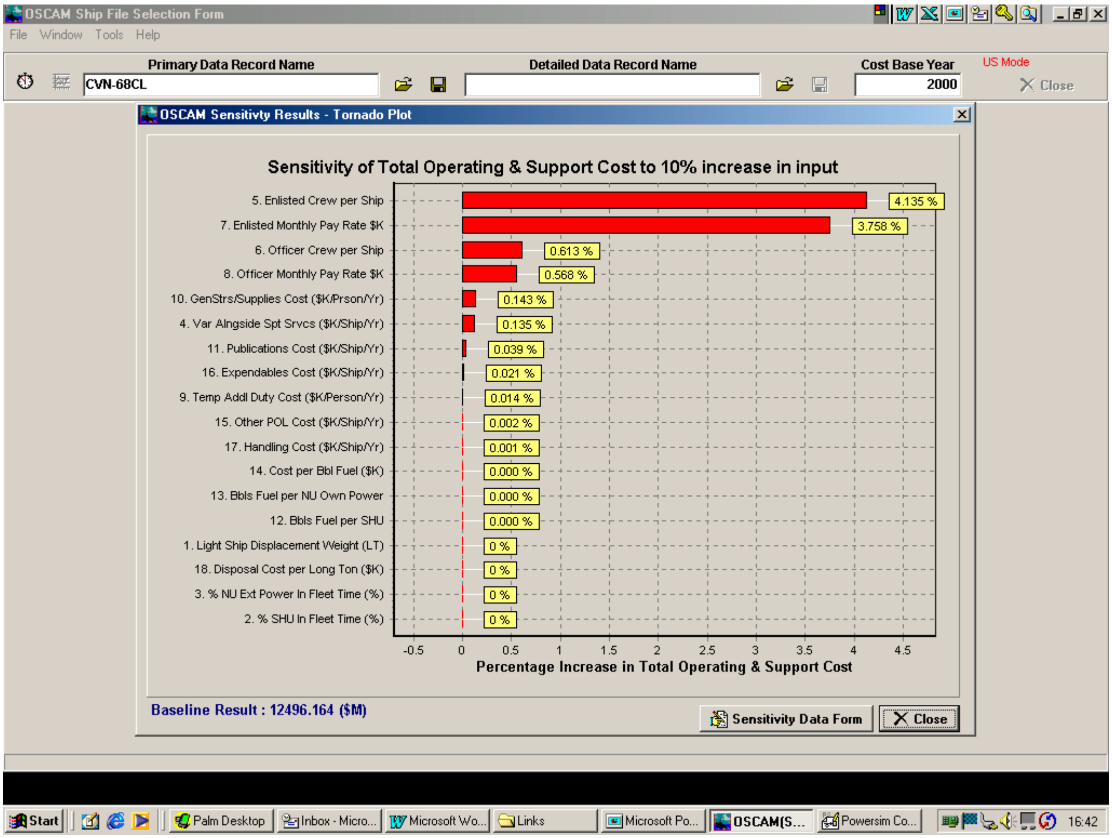


Figure 6. Sensitivity Screen.

31. In figure 6, we have selected a large group of parameters, varied each by 10% and conducted a run for each variable. The screen shot is then showing which variables have the greatest effect on the O&S cost of this ship in this particular operating profile. In this way, we can identify the key cost drivers.

VERIFICATION AND VALIDATION.

32. Each OSCAM model has undergone an extensive verification and validation (V&V) process. This involves all the major stakeholders in that model, the analysts, end user community (especially relevant military organisations) and the developers. To achieve this goal, we conduct three main types of test:

- Descriptive tests. These essentially involve analysing the IDs to ensure that they do accurately represent the process. Whilst this largely involves scrutiny from the end user, there are also a number of procedural tests that can be applied. An example would be the so-called “test of closure”. This simply involves looking at variables on the diagrams that only have arrows coming out of them and asking if they are truly exogenous to the system;
- Mathematical and software tests. These ensure that the model and the software do actually perform the correct calculations at a component level. This includes extreme variable testing; and
- Validation tests. This largely involves running the model against historical cases to see if it accurately mimics known behaviour.

33. Whilst no model can ever be said to be 100% valid, we are confident that each of these models has been through a rigorous V&V process.

OSCAM USE AND EXPERIENCE

34. OSCAM now has a relatively long development experience. In the US, we have trained nearly 200 users predominately from the Navy but increasingly from the Marine Corps and Airforce. In the UK, we have now trained over 80 users mainly in the Naval and Army communities. On both side of the Atlantic, the model has been used by contractors as well as Government analysts.

35. The model has been used to address a number of problem areas including:

- Tender assessment;
- Business case submission; and
- Investment appraisals for new strategies for in service equipment.

36. The model was designed to be used throughout the system life cycle and this has proved to be the case with both new and in service programmes using it. For example, in the US the model was used by the TAKE programme to assess the bids for these ships. All for contractors were asked to submit the O&S element of their bids using the model. They did this with only minimal training from HVR and no consultancy support. At the other extreme, the model was used to assess the pros and cons of implementing RCM across the Hunt Class mine hunters. Whilst overall the conclusion was that RCM did add value, the model clearly showed that there were penalties as well as benefits and, in this way, greatly strengthened the ultimate recommendations of this study.

SUMMARY

37. We hope that we have shown that OSCAM represents a unique and powerful way of assessing O&S costs. As a business process model, the tool differs from typical cost models. This is not to say that it is better than they are, merely that it provides an alternative window onto this type of problem. However, the model is in use on a number of projects such as AAAV and C-17 and has been through an extensive V&V process.

38. OSCAM is an important tool in the armoury for groups, like SPS and WSA, charged with assessing and comparing O&S costs.

39. The UK models are freely available within MoD for trained users and for studies in support of MoD programmes. Organisations outside MoD can procure the models through HVR.

Life Cycle Cost Simulation in Defence Planning

Prof. Jaroslav Komarek
Military Academy
Kounicova str. 65
612 00 Brno
Czech Republic

Summary

Regarding force and armament planning the relatively long life cycle of military systems has to be considered and a total life cycle cost (LCC) in the evaluation of optimal decision reflected. When analysing LCC a cost breakdown structure (CBS) has to be determined as the first step and a cost estimating follows. A variety of methods are available to develop a cost estimate (e.g. parametric, analogous, accounting method, expert opinion) and the methodology chosen depends on the level of detail required, the availability of data, and time constraints. An example of simplified preliminary cost estimate from the Czech Armed Forces is based on the relationship of LCC elements to the cost of acquisition alone. As a decision support tool for defence planning a simulation model ForceSim has been developed. This model is based on the optional scenario portfolio of security risks. Each scenario requires the corresponding kind and number of military systems and when we sum up the demands of all risks regarding possible concurrency and substitution, the outcome is the required structure of defence force pool. But each system represents a corresponding cost demand in the case of activation (initial cost), cost for the operation and support of deployed system, as well cost for the deactivation of a superfluous system (disposal cost). Each phase is quantified for 17 generic military systems by its length and per year cost. In some cases the deployment phase can differ from initial one in prevailing non-investment cost and therefore the possibility of the fourth separate phase is considered. The comparison of total needed cost with disposable budget through 20-year simulation period is solved by System Dynamics model and the outcome can serve for the decision among the different strategies of defence force planning regarding LCC.

Introduction

The need to address total LCC is evident by military systems. There are at least two reasons for it: the dominant proportion of operation and support (O&S) cost compared with acquisition one, and an essential impact on LCC coming from decisions made in the early phases of concept definition and planning. When analysing LCC there is a need for CBS comprising all relevant cost elements. No set method exists for breaking down cost as long as the method used should be tailored to the specific application. Nevertheless Benjamin Blanchard presented a famous example of detailed CBS with almost one hundred elements over twenty years ago and there has been a continuous development on this field up to this time. But the structure is empty without costs, and therefore the second step in LCC analysis has to be a cost estimating.

Cost estimating

A variety of methods are available to develop a cost estimate. The methodology chosen depends on the level of detail required, the availability of data, and time constraints. To identify the best-suited methodology, the analyst must have an understanding of the models and techniques and their applicability. But it is crucial that he (she) must have a clear and complete understanding of the military system requirements.

Cost estimates can be assessed by various methods:

- The straightforward use of current cost is the simplest tool for an approximate analysis.
- Parametric cost estimating involves the development and utilisation of quantified relationships between historical costs and the performance characteristics of system (cost per mile of range, cost per unit weight or volume, cost per unit of reliability, etc.). Its basic premise is that the

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

relationships could be taken either for valid in the future or their trend projection is anticipated.

- Analogous cost estimating is often used when similar system still exists, or a new system is combination of existing subsystems.
- Calculation (Accounting) method uses engineering estimates of reliability, maintainability, and component cost characteristics to build estimates from the "bottom-up" for each component. This is the method of choice when detailed system data and an appropriate LCC estimating model are available.
- Expert opinion, although argumentative, is often the only method available since backup data are scarce, if they exist at all.

Regarding cost estimating process generally, there are more aspects to be considered:

- For purposes of cost estimating LCC are divided into four characteristic phases: research and development, production and deployment, operation and support, and disposal. Depending on the system, costs can peak and overlap at any phase, and when summarised a total LCC profile is visible.
- When comparing more alternatives, the time value of money has to be considered by discounting. The procedure of discounting is simple, however selecting of discount rate is often difficult as it depends on investment opportunities.
- The considering of relevant inflation is necessary as well.
- When accomplishing a process repeatedly, learning takes place and experience gained often results in a cost reduction. The application of learning curves should reflect besides labour cost also "large lot effect" and inventory policy.
- O&S cost estimates are based on peacetime data usually and therefore cost estimates for the most force elements should reflect wartime requirements (combat damage, lack of maintenance, intensive rate of use, etc.).
- Cost estimates should be independent either externally (on industry statements through appropriate own calculations) or internally (on authorities intent).

Simplified case study

As an example of extremely simplified approach to an LCC estimate the recent case from the Czech Armed Forces can be mentioned. The estimating task concerned the total LCC of 36 supersonic fighter aircraft just before a governmental decision whether a call for bids would be announced or not.

The only starting documentation were the draft of Request for bid, and a rough price information delivered to the Ministry of Defence by potential contractors. For a preliminary cost estimate the support-related costs were expressed relatively to the basic price of an aircraft:

Aircraft	Percentage of aircraft basic price		
	Initial logistics	Inclusive of training	25 year O&S
F-16 C/D	18,8	23,2	-
F-18 E/F	-	25,4	-
Mirage 2000	-	25,3	-
Gripen	20,0	-	-
Eurofighter	34,8	-	107,2

Regarding generally accepted 60-70% proportion of O&S cost in LCC and a similar proportion obtained with the help of EDCAS model by the manufacturers of the L-159 light combat aircraft, the following relationship in cost estimate had been accepted (in % of aircraft basic price):

Initial logistic support	20 %	
Elementary training	4 %	
O&S cost (25 years)	150 %	(60 % of LCC)
O&S per year	6 %	

The initial logistics should cover the material requirements of maintenance through the first two years and therefore an approximate 50% reduction of O&S cost had been applied. The preliminary estimate of LCC had been afterwards calculated for each year according to the supposed time schedule of aircraft deployment and operation, both for the minimal (27 mil. US$) and the maximal (64 mil. US$) basic price. Regarding the current tendency of relatively lower portion of O&S cost by the most modern aircraft, an alternative calculation considered the cost data of Eurofighter.

A more challenging task was the cost estimate of training ammunition and operational stockpile owing to the various armaments of multirole fighter, and therefore an essential simplification. Requirements for a routine yearly training were taken from the type F-16, training level COMBAT READY, primarily air-to-air mission. The operational stockpile of ammunition issued both from anticipated combat employment (70% air-to-air, 30% air-to-ground) and the corresponding set of ammunition (cannon rounds, bombs, rockets and missiles) inclusive of launchers and external fuel tanks. Resultant total ammunition cost corresponded to the 48% of total O&S cost for the cheapest aircraft.

This preliminary estimate offered a basic orientation about possible cost range for the further economic and political consideration of defence needs and budget balance regarding debt service, inflation, exchange losses and off-set returns.

LCC in Defence planning

Within the last few years, the needs of defence planners have changed radically, with the collapse of the Warsaw Pact, reductions in defence expenditures in most countries, and growing instability in some parts of the world. There is much uncertainty as to what type of force may be appropriate, what equipment is needed, and what concept of operations might be required in scenarios, which are still unfolding. The time horizon of defence planning must be commensurable with the average life of force structures, and it appears that force structure life times become ever longer. For instance, combat aircraft that used to live for 10 to 20 years in peacetime, now live for 20 or 30 years (or more, e.g. the case of bomber B-52) with capability enhancing mid-life upgrades. There is other related factor that demands a rather long time horizon. The time constants required to change organisation, operational procedures, training and doctrines are significant too. But a defence budget is a key factor that drives the size of defence force, the level of technology implemented, the level of readiness that can be maintained and the amount of research that can be supported to develop new technology. The constraints of the defence budget produce competing demands among various elements of defence force. As requirements almost exceed resources, defence planners must balance these competing demands to achieve effectiveness and affordability.

As a decision support tool for the long-term force planning by restraint resources a simulation model ForceSim has been developed. The model is based on an optional combination of risks that creates a scenario portfolio. Each of risks requires the corresponding kind and number of military units for to be eliminated and when the demand of all risks is summed up regarding possible concurrence and substitution, the outcome is needed structure of defence force pool. The model force structure has been simplified to 17 main branch units (military systems), e.g. Ground Heavy Offensive (tank or mechanised units), Ground Heavy Defensive (armoured artillery), Ground Light Offensive (light infantry, reconnaissance units), … Air Defence Short-range, …Airlift Long-range, … ENG, C3I, EW, NBC Defence etc. The input of the corresponding number of units has to be determined for the four basic security risks (Out-of-area conflict, Territorial conflict, Terrorism and Non combat threat) regarding the further combination of various scenarios by characteristic aspects of a conflict: technology (T1- low, T2- high), intensity (I1- low, I2- high) and area (A1- local, A2- regional). The initial database results from mental simulation produced by military experts in the operational environment of analysed country.

Risk	Out-of-area conflict								Territorial conflict							
Aspects	T 1				T 2				T 1				T 2			
	I 1		I 2		I 1		I 2		I 1		I2		I 1		I 2	
	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2	A1	
GHO	0	0	2	3	2	3	3	4	2	3	4	6	4	6	4	
GHD	0	0	1	1	1	1	2	2	0	1	2	3	2	3	4	
GLO	1	1	3	3	0	0	0	0	2	2	4	4	2	3	4	
GLD	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	
ADS	0	0	0	1	0	0	1	2	2	3	2	3	3	4	3	

Each unit represents at the same time a certain cost demand in the case of the activation of a new unit and the cost for the operation of an existing unit as well for the de-activation of a superfluous unit (according to the current structure). In some cases the deployment phase can differ from initial acquisition in prevailing non-investment costs (e.g. primary training before routine operation) and therefore the possibility of separate fourth phase is considered. The cost demand for each change of force structure represents in fact an expansion program with a rectangular cost profile, but when divided to several subprograms, the growth of cost profile can be simulated. The cost demand for a reduction program (de-activation) rolls down every year automatically. The time schedule of programs has to be set at the beginning of simulation and thus enables to reflect intentional development strategy. The comparison of the cost demand with disposable budget is solved in the model by System Dynamics simulation and the expected defence budget (derived from GDP grow rate) is compared with the defence force cost yearly through the 20-year simulation period. Beginning with starting year the summarised cost demand is compared with the regular year budget and an uncovered activation is postponed into the next year automatically. The amount of postponed activation shows a financial imbalance and has to be corrected in the further run of simulation either by the time shifting of activation or de-activation programs and subprograms, or by proposal of less costing system.

Elements	Need (N)	Activation		De-activation		Operation	Subprograms					
							1		2		3	
		Years	Cost per year	Years	Cost per year	Cost per year	N 1	Year	N 2	Year	N 3	
GHO1	2	3	500	4	50	100	1	2004	1	2008		
GHO2	4	5	150	2	20	30	2	2006	2	2012		
GHO3	2	5	50	1	10	10	2	2010				
GHD1	-1	3	300	4	40	80	-1	2002				
GHD2	-2	5	100	2	20	30	-2	2002				

The outcomes of simulation can serve for the decision among the different strategies of defence force planning under restraint resources. It is necessary to stress that even though the simulation model ForceSim is significantly simplified (so called “quick and dirty” model), the data demand is rather high. Nevertheless the important advantage of this model is the variability of data utilisation for a lot of operational and budget development scenarios.

Bibliography

Blanchard, B., *Logistic Engineering and Management.* Englewood Cliffs, N.J.: Prentice-Hall, 1981.

“AFMC-Develop Preliminary Cost Estimate.” HQ AFMC, 2000.

“Cost of Ownership Guidebook.” NAVAIR, 1996.

Komarek, J., et al., *The Preliminary LCC Analysis of a Multirole Supersonic Fighter Aircraft.* Brno: Military Academy, 2000 (in Czech).

Click here to view PowerPoint presentation; Press Esc to exit

L'élaboration de modèles spécifiques à la DGA

Albane Capy et Christophe Pereira
DGA/DPM/SDA/EC
26, boulevard Victor
00457 Armées
France

La **Délégation Générale pour l'Armement** (DGA) est un organisme du Ministère de la Défense français « chargé de fournir aux armées françaises les matériels qui leur sont nécessaires, au meilleur coût ».

L'**estimation des coûts** à la DGA concourt à la maîtrise du coût des programmes d'armement comme outil d'aide à la décision pour la préparation puis la réalisation de programmes.

L'utilisation des premières méthodes « scientifiques » d'estimation de coût à la DGA date du début des années 80. Au milieu des années 90, les estimateurs de coûts disposent d'un premier modèle d'estimation spécifique de coûts élaborés par leur soin dans le domaine des blindés.

Cet article traite de **l'élaboration des modèles spécifiques** dans l'environnement DGA c'est à dire un organisme **étatique** (il ne développe ni ne fabrique de produits) et **militaire** (les projets sont par essence complexes, à haute teneur technologique et s'étalent sur plusieurs années).

Les définitions des objets intervenant dans la constitution des modèles et les étapes de la modélisation sont successivement exposées. Puis, sont abordés les méthodes de régression et les critères statistiques à examiner. Enfin, on insistera sur l'utilisation des modèles spécifiques et les principaux écueils rencontrés.

A titre d'illustration, un exemple, le modèle **MOPSOS**, est repris tout au long de l'exposé.

1. QUELQUES DEFINITIONS

Le développement d'une **Formule d'Estimation de Coûts (F.E.C.)** part du recueil et de la normalisation des coûts pour aboutir à une formulation mathématique du coût en fonction de paramètres explicatifs (caractéristiques techniques, niveau de performances, caractéristiques organisationnelles, …), spécifiques à chaque famille de produit.

Le but est de mettre en évidence sur une famille spécifique de produits les évolutions du coût, de les expliquer pour ensuite les prévoir.

Communication présentée lors du symposium RTO SAS sur les « Structures de coûts et coûts globaux de possession (LCC) pour systèmes militaires », organisé à Paris, France, du 24 au 25 octobre 2001, et éditée dans RTO-MP-096.

Un **modèle d'estimation paramétrique de coûts** de matériels lie par une ou plusieurs relation(s) mathématique(s) le coût à un ou plusieurs descripteurs techniques, économiques et/ou organisationnels. Sa finalité est de **prévoir le coût à partir d'un nombre réduit de paramètres**, généralement en amont d'un projet lorsque peu d'informations sont disponibles.

Un modèle d'estimation paramétrique de coûts est dit **spécifique** lorsqu'il est établi sur et pour une famille donnée de matériels (à titre d'exemple : les véhicules blindés français, les moteurs d'avion, ...). L'établissement de modèles spécifiques s'appuie sur le recueil et l'analyse d'informations techniques et économiques sur cette famille et consiste à établir des équations :

- **COUT = F(caractéristiques et/ou performances)**

A titre d'exemple, le modèle **MOPSOS** de prévision de coûts de production de blindés français permet de quantifier le coût de production d'un véhicule blindé à partir de sa définition. L'objectif initial de ces travaux était d'être capable de faire une estimation de coûts raisonnable avec peu d'informations très en amont dans la vie d'un blindé. Les équations de coût de blindés obtenues répondent aux exigences de la prospective : elles font intervenir des caractéristiques objectives, facilement quantifiables et connues très tôt dans le déroulement d'un programme.

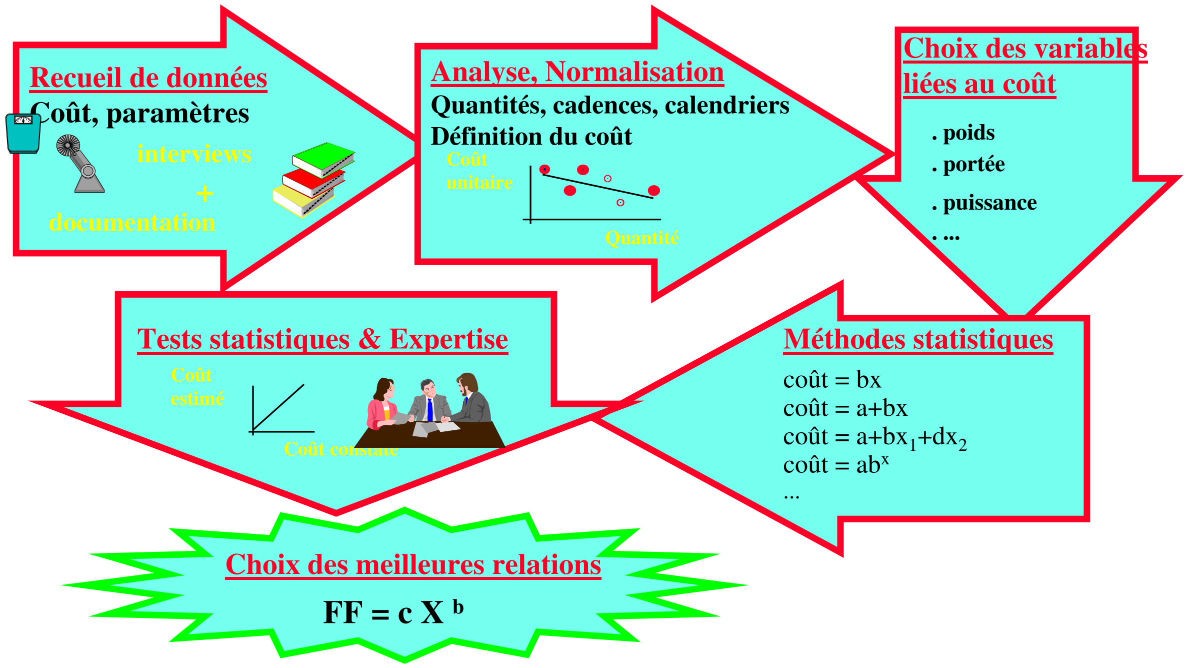
Le modèle MOPSOS est un outil de gestion d'hypothèses de définition et/ou de conception.

2. LES ETAPES DE LA MODELISATION

La qualité d'un modèle spécifique de coûts est **liée au nombre de programmes de référence** qui auront servi à sa constitution et **au respect des différentes étapes nécessaires à sa construction** (pertinence des données, analyse statistique des données, recherche de la formulation mathématique la plus adaptée, test de qualité,...).

L'élaboration d'équations spécifiques s'articule autour de **cinq étapes successives** :

1. **le choix de la famille de référence** pour établir le modèle,
2. **le recueil d'informations** techniques et économiques sur la famille,
3. **l'analyse et la normalisation des coûts**,
4. la mise en œuvre de **traitements statistiques**,
5. **la sélection des « meilleures » équations** spécifiques.



<u>Les étapes de l'élaboration de modèles spécifiques d'estimation de coûts</u>

2.1. LE CHOIX DE LA FAMILLE

Le choix de la famille et de ses membres s'effectue en fonction :

• **du <u>nombre</u> de produits** ou, en termes statistiques, **<u>d'individus</u>** présents dans la famille : si la famille compte moins de quatre individus, elle ne permettra pas d'élaborer de modèle spécifique,

• de **<u>l'existence, de la disponibilité et de la fiabilité des informations de coûts</u>** et des informations de nature technique (masse, dimensions, performances, ...) ou organisationnelle (existence d'une coopération, nombre de chaînes de fabrication, ...).

• du **<u>caractère homogène</u>** de la famille qui amène à se poser les questions suivantes : les caractéristiques techniques sont-elles identiques pour tous les individus de la famille, la formation des coûts est-elle semblable d'un individu à l'autre, ...

En estimation de coût en général et pour les projets militaires encore plus, le nombre réduit de produits distincts dans une famille donnée est un des principaux freins à la constitution de modèles spécifiques. Pour MOPSOS, c'est un demi siècle de véhicules blindés français qui a permis de constituer une famille d'une dizaine de véhicules. Cependant, remonter dans le temps n'est pas sans danger. Cela a des effets négatifs sur le recueil des informations, en particulier sur les informations de coûts (informations perdues, homogénéité des définitions au cours du temps, manque de précision, difficulté de mise à jour économique ….)

Un arbitrage est à faire entre une famille réduite (quelques individus) mais homogène et une large famille composite.

On pourra penser par exemple mélanger des individus de nationalités différentes (des missiles français et américains), de milieux différents (des avions civils et militaires), de type différent (des sous-marins et des navires de surface).

Il est possible de partir d'une grande famille et de raisonner par sous-famille par la suite, mais réduire le nombre d'individus a pour effet de diminuer le nombre de variables de l'équation. En effet, il est conseillé d'avoir au moins quatre individus pour un modèle à une variable ; ainsi pour dix individus, les équations de prévisions pourront compter deux à trois variables.

Une approche en sous-familles permet de raisonner à un niveau plus homogène, d'introduire dans les modèles des caractéristiques et/ou performances plus spécifiques à un type de matériel donné.

2.2. LE RECUEIL D'INFORMATIONS TECHNIQUES ET ECONOMIQUES

Il s'agit de bâtir **un historique technique et économique de la famille de produits** : c'est-à-dire répertorier les caractéristiques techniques et/ou les performances caractérisant la famille et relever les informations économiques constatées sur les matériels de la famille. Ce recueil nécessite de rencontrer les spécialistes techniques du domaine, les acheteurs négociateurs et les enquêteurs de coûts des principales sociétés impliquées dans la fabrication de la famille.

Les données à recueillir sont de trois types :

– les **descripteurs** techniques, candidats potentiels à intégrer les équations de coût,

– la variable économique : le **coût**, variable à modéliser puis à prévoir,

– les **caractéristiques de programme** (quantités, délais, …) associées au coût.

La phase de recueil est une étape-clef, consommatrice de temps, très itérative.

2.3. L'ANALYSE ET LA NORMALISATION DES COUTS

Les données de coûts recueillies à l'étape précédente sont **des données brutes**.

Chaque coût observé sur un produit existant est attaché à des conditions d'établissement différentes et peut provenir de sources d'informations différentes. Ces coûts bruts sont à normaliser, c'est à dire qu'il faut les ramener à un ensemble unique de conditions.

Ainsi, il est impératif d'avoir :

- une **définition précise et homogène du coût** ou du prix, le coût de production (hors marges et frais hors production) est à privilégier,
- la **même unité monétaire** et les **mêmes conditions économiques** (choix de tables ou de formules de mise à jour des coûts),
- une **quantité unique** (choix de dégressivité),
- voire une **cadence de fabrication unique**.

Raisonner à quantité donnée (par exemple, le coût des 100 premiers véhicules blindés) a pour avantage de ne pas utiliser la variable quantité dans l'équation de régression. Ainsi, d'autres variables explicatives peuvent figurer dans l'équation quand la famille des matériels est de taille réduite.

Un travail d'analyse et de validation est également à fournir sur les données techniques recueillies mais il est souvent de moindre ampleur que sur les données de coûts. Il s'agit de consolider les données techniques en provenance de sources différentes (s'assurer que l'information n'est pas susceptible d'évoluer) ou rechercher les informations manquantes (sur les matériels les plus anciens). Des variables techniques combinées peuvent être formées sous forme de ratios par exemples.

A l'issue de cette troisième étape, on dispose de la variable à prévoir : le coût normalisé et d'un ensemble de variables prédictives potentielles.

2.4. - LA MISE EN ŒUVRE DE TRAITEMENTS STATISTIQUES

Une fois les étapes précédentes effectuées, la phase de modélisation statistique va permettre de mettre en évidence **les facteurs** qui ont une **influence mesurable** sur les coûts. La méthodologie adoptée consiste à relier statistiquement le coût avec un nombre réduit de descripteurs se rapportant aux aspects techniques et aux performances de la famille, à l'organisation industrielle et aux caractéristiques des programmes.

Les traitements statistiques consistent à mettre en œuvre :

1. **les techniques d'Analyse de Données** : recherche de liens (entre les caractéristiques et les matériels, entre les caractéristiques elles-mêmes, entre les matériels eux-mêmes), identification des facteurs discriminants, <u>visualisation synthétique des données</u>, détection de points atypiques. Cette étape est facultative, mais se révèle intéressante lorsque les données sont nombreuses.

2. **les techniques économétriques** : **mise en évidence des liens techniques et logiques existants entre les variables et le coût** pour obtenir un outil de prévision, le principe général de la régression étant la minimisation des écarts entre valeurs prédites et valeurs observées.

A titre d’exemple, l’utilisation de l'Analyse Factorielle des Correspondances sur les blindés a guidé la constitution de deux sous-familles, d’une part la sous-famille des chars (blindés lourds), d’autre part celle des blindés de reconnaissance et de transport de troupes (plus légers).

La recherche de modèles prédictifs peut s’effectuer par balayage de toutes les combinaisons possibles de variables et par test de plusieurs types de formulations mathématiques.

Le travail itératif de **sélection de modèles**, coûteux en temps, et l'**application des techniques statistiques** constituent les difficultés inhérentes à cette étape mais renforce la qualité statistique et prédictive des modèles obtenus.

2.5. - LA SELECTION DES EQUATIONS SPECIFIQUES

La sélection d'un **ensemble convenable de relations coûts/caractéristiques** s’appuie sur la validation statistique et l’expertise des modèles.

Plus précisément, cette étape de sélection consiste à :

- mettre en œuvre de **tests** (qualité statistique, robustesse),
- examiner des **écarts individuels entre coûts estimés et coûts observés**,
- **accepter** ou non **des modèles** selon la pertinence des variables qu'ils font intervenir,
- examiner la **capacité prédictive** des modèles sur les **produits les plus récents**.

Le recours systématique à la validation technique et/ou opérationnelle des modèles mis en évidence est indispensable.

De façon générale, le recours à l’expertise des techniciens ou des utilisateurs du matériel pour délimiter les sous-familles, sélectionner les meilleures équations est toujours nécessaire.

3. LA REGRESSION MULTIPLE

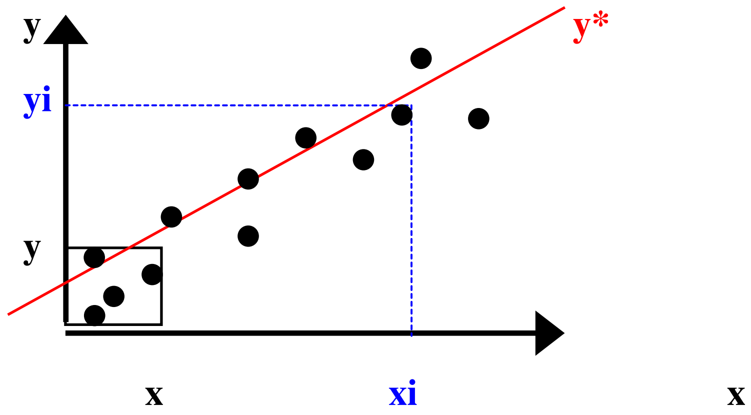
3.1. RAPPEL SUR LES PRINCIPES DE BASE

La méthode de régression multiple est utilisée pour **déterminer des relations entre le coût et les variables prédictives**.

La recherche de modèles explicatifs conduit à tester plusieurs types d'équation de comportement. Quatre formes-types - ou des combinaisons entre ces formes-types - peuvent être envisagées : linéaire, exponentielle, multiplicative et logarithmique.

La forme multiplicative donne généralement les meilleurs résultats en matière d'estimation de coûts. Les quatre formes de modèles peuvent se ramener à une équation de régression linéaire par un changement de variables.

Dans le plan (p = 2), la méthode de régression linéaire ajuste au nuage de points une droite qui minimise la somme des écarts au carré entre valeurs observées et valeurs prédites (algorithme des Moindres Carrés Ordinaires : MCO).



3.2. LES VARIABLES PREDICTIVES POTENTIELLES

Pour intégrer une équation de coût, une variable doit nécessairement :

• **être reliée de façon logique au coût** : pour s'en assurer, il suffit de regarder les coefficients de corrélation entre variable à prévoir (le coût) et variable prédictive,

• **être disponible suffisamment tôt** dans la vie d'un produit,

• **être connue avec un certain degré de précision**.

Les avis divergent sur le nombre de variables à introduire dans une équation par rapport au nombre d'individus. Il faut au moins **un individu de plus que de variable** : pour une famille de 10 produits, le nombre maximum de variables est 9 (dans le cas contraire, les méthodes de régression ne sont pas applicables). Cependant, pour mettre en œuvre des tests statistiques valides, **un minimum de 4 individus est requis pour établir une formule de régression à une variable** (au plus 2 variables pour une famille de 10 matériels)

Elargir le nombre des variables dans une équation a pour conséquence de réduire la capacité prédictive ; cependant des modèles avec une variable supplémentaire (trois variables au total pour une famille de 10 individus) peuvent être conservés dans la mesure où ils apportent une information supplémentaire.

En effet, ajouter une variable revient à injecter dans l'équation un a priori qui met en cause la validité statistique **des problèmes de colinéarité** des variables présentes dans le modèle surviennent, **le modèle devient trop descriptif** et **perd ses qualités d'extrapolation**.

4. LES CRITERES D'EVALUATION D'UN MODELE

Les relations de coûts sont évaluées sur la base de leur qualité statistique, de leur conformité à un comportement rationnel vis à vis du coût et de leur capacité de prédiction.

4.1. – LES CRITERES STATISTIQUES

Au regard des propriétés statistiques, les équations à conserver doivent satisfaire les critères suivants :

- le coût et les variables explicatives (ou leurs transformées) sont **liés par une relation linéaire**,

Le degré de variation expliqué par l'équation de régression (mesuré par le coefficient de détermination) est important.

- les variables prises collectivement ont une influence significative sur le coût (test de Fisher) avec un niveau de probabilité donnée (90 % ou 95 % ou ...),

- **l'erreur standard d'estimation** (SEE) est **minimisée**, cette erreur peut être transcrite en pourcentage de variation sur le coût (20 %, 15 %, …)

- chaque variable est significative (test de Student) avec un niveau de probabilité à définir (90 % ou 95 % ou 99%, ...),

Ne sont retenues dans l'équation que les variables pour lesquelles le coefficient est nettement différent de 0 (la mesure de la différence dépend de la probabilité choisie, souvent 95 %).

- les variables ne sont pas corrélées entre elles,

Des variables dont les corrélations linéaires sont supérieures à un seuil donné (0,7 à 0,8 en général) ne peuvent être ensemble dans une équation.

- **l'analyse des résidus est satisfaisante** (respect des propriétés de variance constante et de non-corrélation).

L'étude des résidus permet de repérer les observations aberrantes (distance de Cook), les observations qui jouent un rôle important dans la détermination de la régression.

4.2. - LA RATIONALITE

Développer des équations de coûts nécessite que les coefficients des variables fournissent des résultats crédibles et conformes autant que possible à la procédure normale d'estimation de coût.

Les signes et l'ampleur des coefficients dans les équations doivent être

cohérents avec la notion intuitive de l'évolution de la variable. A titre d'exemple pour les blindés, la variable masse doit apparaître avec un signe positif dans l'équation (quand la masse augmente, le coût augmente).

Pour vérifier **la stabilité des coefficients**, il est judicieux de comparer le coefficient et son écart-type qui ne doivent pas être dans le même ordre de grandeur. La source principale d'instabilité des coefficients est le cas où les variables explicatives sont très corrélées entre elles.

Il est impératif de **faire approuver les équations par des spécialistes techniques et les acheteurs du domaine** en validant avec eux que les variables retenues dans l'équation ont bien une influence sur les coûts et qu'il accepte le signe et l'ordre de grandeur du coefficient. A titre d'exemple, sur le modèle MOPSOS certaines équations ont été rejetées par les experts alors que leurs propriétés statistiques étaient correctes.

4.3. LES PROPRIETES PREDICTIVES

Une façon de tester la qualité prédictive est de retirer de l'échantillon le ou les systèmes les plus récents ou extrêmes en caractéristiques et/ou en coût afin de voir comment (en terme de déviation) l'équation résultante estime le système exclu.

5. L'UTILISATION D'UN MODELE SPECIFIQUE

Il est impératif d'établir des règles de bonne utilisation des modèles spécifiques.

Au préalable, il faut s'**assurer de l'appartenance à la famille du produit à évaluer**. Cette première règle en apparence simple peut être difficile à suivre.

Quand, par exemple il y a un changement de technologie majeure, il est évident pour tous que le résultat du modèle est à examiner avec précaution. Par contre quand le produit à évaluer est de même nature mais nettement plus petit que les produits ayant servis à l'élaboration du modèle, le doute sur la validité du résultat n'est pas toujours acquis. Ainsi, il est judicieux de déterminer pour tous les paramètres des plages de variation admissibles. Ainsi, si un ou plusieurs paramètres sortent de la plage, l'utilisateur sera alerté.

Pour le modèle MOPSOS, des plages de variation ont été définies pour tous les paramètres.

Il faut disposer d'une **définition claire et précise de tous les paramètres intervenants dans l'équation** aussi bien la variable de sortie, le coût que les variables d'entrée et s'assurer que les données d'entrées sont conformes à leur définition (unité de mesure, …).

A titre d'exemple, la masse d'un blindé peut varier d'une à plusieurs tonnes entre masse à vide et masse en ordre de combat. Ou encore, parler de masse d'électronique peut avoir plusieurs interprétations : entre les cartes et composants seulement et le boîtier électronique complet (avec sa structure) on passe du simple au triple.

Ces premières règles s'accompagnent d'une règle plus délicate à observer : il s'agit de valider la **cohérence des paramètres d'entrée entre eux**, en somme, de s'assurer que le produit est « viable ». Pour cela, le modèle d'estimation peut comporter des règles dites d'architecture permettant de valider la cohérence de la définition du produit. Par exemple, pour un blindé, il faut valider l' « harmonie » du trio masse, puissance du moteur et vitesse maximale.

Il est nécessaire de **s'assurer également de l'actualité du modèle**. Utiliser sur des produits d'aujourd'hui un modèle des années 80 n'est pas pertinent. Cela ne permet pas de prendre en compte les évolutions techniques, technologiques ou organisationnelles intervenues depuis 20 ans. Il est nécessaire d'intégrer les évolutions de façon progressive. La **mise à jour du modèle est impérative** pour conserver la confiance.

Ainsi pour le modèle MOPSOS, à la signature du marché d'un nouveau véhicule blindé, la **procédure de mise à jour du modèle** peut démarrer. Elle consiste en plusieurs étapes :

1. recueil des paramètres sur le nouveau blindé (mise à jour de la base de données MOPSOS) et utilisation du modèle MOPSOS pour prévoir son coût,

2. analyser les écarts entre le coût estimé et celui du marché (à définition équivalente),

3. intégrer le nouveau véhicule dans la famille des blindés pour recalculer avec ce nouveau blindé les formules d'estimation de coûts, effectuer une nouvelle recherche d'équations pertinentes,

4. sélectionner un nouvel ensemble d'équations en examinant les tests statistiques des nouvelles formules et en demandant le concours des experts techniques du domaine,

5. mettre à jour la maquette informatique avec les nouvelles équations.

6. CONCLUSION

L'ensemble de données recueillies est à analyser avec une exigence commune : travailler avec le moins d'a priori possible et de la façon la plus exhaustive tout en restant cohérent (définition unique des coûts, définition stricte et précise des variables).

Les difficultés rencontrées peuvent principalement concerner :

- le travail de familiarisation avec la famille de matériels,
- l'élaboration d'une base de données exhaustive et cohérente,
- la normalisation des coûts,
- l'expertise sur les variables potentiellement déterminantes.

L'utilisateur des modèles spécifiques veillera à :

- ❖ adopter la même définition des variables que celle utilisée dans les modèles,
- ❖ rester assez proche des valeurs rencontrées dans l'échantillon de base,
- ❖ assurer la cohérence des valeurs qu'il donne aux différents paramètres.

Lorsqu'un nouveau membre de la famille apparaît, les équations de prévisions sont à mettre à jour (test des anciennes équations, calcul de nouveaux coefficients).

Les modèles d'estimation de coût spécifique à la DGA ont été jusqu'à aujourd'hui centrés sur les coût d'acquisition de programmes militaires.

Il est prévu d'étendre les capacités du modèle MOPSOS au coût de possession des blindés en collaboration avec les organismes chargés du maintien en condition opérationnelle. De façon plus générale, la DGA devrait s'orienter vers l 'élaboration et l'acquisition de modèle d'estimation de coûts du cycle de vie.

Page intentionnellement blanche

This page has been deliberately left blank

Click here to view PowerPoint presentation; Press Esc to exit

A Software Support Cost Model for Military Systems

Julian Gibbs, BSc, DMS, MIMgt
Principal Consultant, Whole Life Economics
BMT Reliability Consultants Ltd
12 Little Park Farm Road
Fareham, Hampshire
PO15 5SU
United Kingdom

Seriously Expensive ?

Research has shown that, for every £1 spent on developing and acquiring computing software, at least £2 and, particularly for bespoke operational software, sometimes in excess of £20 is spent maintaining it.

1. INTRODUCTION

This paper presents a description of the background, history and successful completion of a programme of work to develop and implement a model to predict the cost of supporting military software. This programme, which was carried out for the UK Ministry of Defence, has resulted in a model which is now available to project teams and which brought a number of surprises to us as we brought the development work to a conclusion. These surprises have caused us to consider the nature of software support cost and what aspects need to be addressed as it is used, and in the future.

Although we have only looked at UK projects for military software, we do not believe that there are significant differences between the UK and other NATO or PfP countries and their projects which would invalidate the model. In fact, we would be very pleased to hear from any others with experience in this area.

We believe that we have established a world first in the completion of this model in terms of its foundation, the size of the database, the number of cost drivers, and the final relationship.

The work was carried out under contract to the UK Ministry of Defence Specialist Procurement Services/Cost Forecasting (SPS/CF) in the Defence Procurement Agency at

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

Abbey Wood, Bristol. The views expressed in this presentation are those of the author and do not necessarily represent Ministry of Defence policy.

2. PROBLEM AREA

The UK, in common with other nations, spends a significant proportion of its defence budget on supporting equipment - both hardware and software. Hardware support is usually a visible commodity with the repair or replacement of items of equipment and a consequent logistic loop for which spares are bought and consumed. Such consumption can usually be related to the equipment population and usage: the greater the population or usage, the greater the demand for support and the consumption of spares. This situation is recognised and accepted - or perhaps tolerated - as inevitable. Initiatives such as Integrated Logistic Support which encourage Designing for Support are aimed at reducing the consequential support costs and thus the Life Cycle Costs and there is evidence of a much greater awareness of support issues at the design stage than there used to be.

However, the support activities for software are less clear. There is no requirement for repair or replacement of hardware, only modifications or updates to software. The demand for such changes comes about not only for correcting errors found in the software itself, but also for keeping up with new operational demands, software system upgrades (e.g., new versions of operating systems), and hardware changes, few of which are related to population or usage.

In the UK, the current estimate for the cost of support is £4854M[1] ($7040M), 21% of the total planned expenditure. This in itself is a reduction of 2.4% in real terms on the budget for the previous year and reflects a continuing pressure to reduce the annual defence budget. It is not clear is how much of the budget is spent on software but there is a growing belief that the proportion spent on software is increasing year on year, and that there are few methods for measuring or controlling it.

There are models which claim to be able to predict the cost of procuring and supporting software. However, there is some doubt about their capability and value since they all tend to produce different answers and they all operate in different ways. There is a common practice of taking the average of all of the results as the best estimate, but this is more for convenience than for correctness, and is not a guarantee of success.

[1] Vote 1F, Government Expenditure Plans 2000/2001 to 2001/2002, Cm 4608

As a result of the uncertainty surrounding software cost estimates, and the pressure to reduce the Defence budget being applied particularly to support, two particular targets were set for the development of a Software Support Cost Model:

- to understand what is meant by software support
- to quantify the costs, and the cost drivers, and thereby gain control.

This was the background to the development and implementation of the Software Support Cost Model - the SSCM.

3. SOLUTION APPROACH

The MoD's requirements for SSCM were for a model with a degree of substantiation behind it - i.e., a model with traceability. Other requirements were that it should be based on defence equipment, it should address operational software (rather than office software), and should be available to project managers at their desks.

The approach to solving the problem followed four steps:

- Propose an Outline Model
- Collect data from existing projects
- Test the Model, Refine, Test, Refine and Test again
- Finalise and Issue.

3.1 Propose an Outline Model

Using a Delphi-type approach, we undertook literature and internet searches to identify potential software support cost drivers. We spoke to software experts in the UK and to project managers again with the aim of compiling a list of drivers. We also used the opportunity to identify any models of software support of which we were unaware.

The resulting set of cost drivers was reviewed and an ordered list was compiled starting with the most frequently named items. This formed the basis of the Outline Model.

3.2 Data

Data was collected from projects using a questionnaire. An initial questionnaire was sent to all MoD projects which potentially had operational software under support. This asked for confirmation of such software and that data on the software, its costs and other details could

be provided. Questionnaires were sent to 134 projects and 91 of these responded, most of them offering data. A number of these were selected to receive a second, more detailed questionnaire. Selection of projects was aimed at achieving as wide a coverage of projects as possible. The more detailed questionnaire contained 52 questions relating to parameters and information such as:

- Size
- Cost
- Language
- Application
- Age
- Type of Support
- Development
- Technical requirements
- Project Team
- Planned Life
- Contract arrangements
- Documentation
- Number of Users
- Number of Installations
- Criticality

Data was initially collected from 15 projects (21 had been requested). Only a proportion of the target population of 91 was used initially, partly to test the questionnaire and partly to limit the scale of work.

It became clear during this and subsequent data collections that there was no consistent manner in which such data is recorded, nor any guidance to projects on its collection. To aid our own work in future, and to encourage projects to maintain visibility of their software support costs, we will be providing a template and assistance for recording and tracking this information.

The data collected from 14 of the 15 projects was analysed using multiple regression to identify potential models. Some relationships were found which, although not of particularly high quality, indicated that there was potential to achieve a satisfactory outcome, given a wider population. We viewed this as a positive result and set out to progress the programme by collecting data from more projects and developing the model.

3.3 Further Data Collection and Model Refinement

The above process was repeated a further two times, increasing the population first by 27 projects and then by a further 7 to a total of 48, and refining the modelling approach by considering logarithmic and 2nd order parameters. At the end of the third cycle, we decided that we had established a sufficient model from the data available to stop at that stage and progress to final model issue. We used statistical confidence testing on the model at each stage to determine if the parameters we were using were actually contributing to the

relationship or not. This resulted in the exclusion of some parameters which surprised us but for which the statistical evidence was definite.

These cycles lasted several months. We had difficulty in getting projects to return their questionnaires, and much time was spent in analysing and re-analysing the data, using different sets of parameters. In all we believe we evaluated over 500 different relationships.

At each stage of the project we submitted our methods and results to independent scrutiny. This was to ensure that our results were justifiable, and that there were no errors or omissions in the processes we were using. It would also enable us at the end of the work to meet the MoD requirement that the results should be traceable.

3.4 Finalise and Issue

At the conclusion of the modelling work we had a mathematical relationship for software support costs from a database of 48 projects using only 5 input parameters and with an excellent coefficient of correlation. This was turned into a web-enabled model using pull-down menus to select parameters and an output sheet to provide the results. This has been presented and issued to projects for their own use as and when required.

4. RESULTS - THE MODEL

As stated above, we achieved a model based on 48 projects. All the data used came from the projects themselves: there was no estimation of any of the parameters. The model uses only 5 input parameters, as follows:

- **War Fighting**
- **"Stability"**
- **Age**
- **Contract Type**
- **Application Type**

and with a correlation of better than 0.9

War Fighting is defined as whether the software is essential to the mission.

Stability reflects the likely rate of demand for support based on the variety of (new) operational environments: some systems see very little demand, others see a lot.

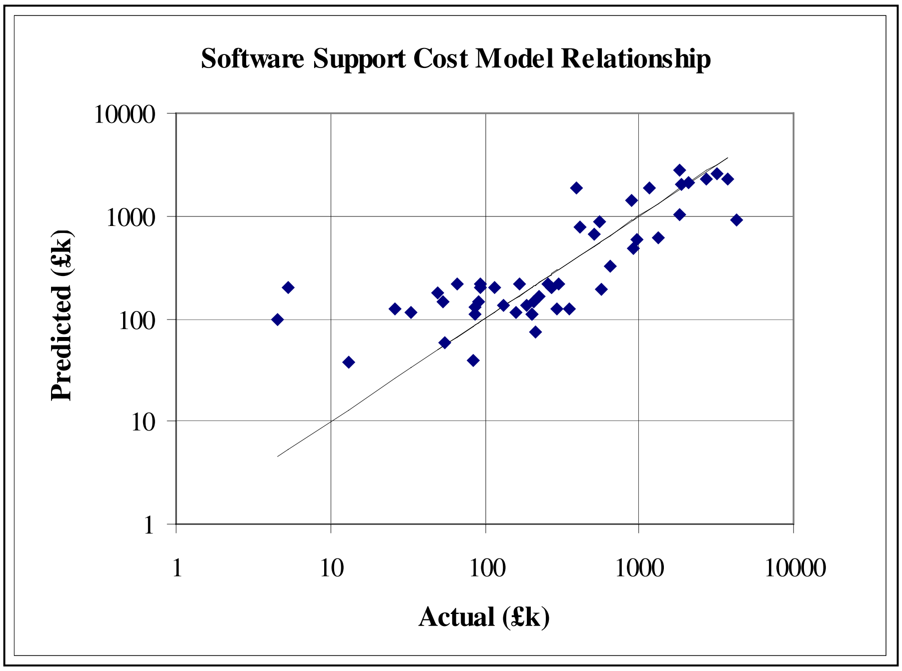
Age is the number of years from the first installation and is the only parameter with a second order coefficient. The two age parameters results in a support cost which peaks at 8 years.

Contract and Application are selected from a list of possible types: in fact, only one type of contract (fixed price) and one type of application (training) appeared to be significant.

A common characteristic of these input parameters is that they can all be set exactly: there is no requirement for subjective judgement by the user - often a weakness in LCC models.

Given these inputs the model can calculate year by year costs and, using information on the spread of data, it can also calculate costs for various confidence limits.

Graphically, the actual values, and the predictions, are as follows:



Statistics

Population:	**48**
Outliers:	**2**
Parameters:	**5**
Ds of Freedom:	**39**
Correlation:	**0.9**

5. OBSERVATIONS

The most obvious observation is that Size is missing from the relationship. Almost all software prediction tools rely on some measure of size as an input parameter. It is natural to expect that the bigger the software, the bigger the support and its cost. Exactly the same comments could be applied to the Number of Users and the Number of Installations. Statistically, however, they did not contribute to the relationship and had to be excluded.

The absence of these parameters caused us to consider the nature of the software support costs which we had modelled. We have concluded that what we have modelled is not so much the <u>cost</u> of software support but rather the <u>price</u> which the MoD (in this instance) is prepared to pay for it. Almost all projects were cash-limited, resulting in only so much budget being made available. In this respect, it can be understood that software size and user base are not significant: what does matter to the MoD is whether the software is

essential to the front line activity and in what operational environment it might have to work.

The SSCM therefore shows project managers what budget is likely to be acceptable. In terms of usefulness of this output rather than what was believed to be the original aim, this result is considered to be of more benefit.

What we have not yet been able to ascertain is how much support was demanded and not met, consequently how much of the software's operational capability might have been compromised. This is another aspect for the future.

Having established a database of defence software projects, the long term aim is to continue to monitor software support costs, and to improve the detail of the data collected. In particular, we want to expand the range of projects to include Commercial Off The Shelf (COTS) and Safety Critical software as these are aspects which currently fall outside.

6. CONCLUSIONS

We set out to create a model for project managers to use to help them forecast the costs of software support, and in this we have been successful. In achieving this success, we have found some surprising results which have caused us to consider the nature of the software support task itself.

The most surprising result has been that the size of the software, and the size of the user base are not significant in determining the cost of software support. What are significant are the military essentiality, the operational environment, the age and the contractual conditions.

The resulting model is deceptively simple in terms of the number of parameters, and statistically remarkably accurate in terms of a 90% correlation with real data, particularly given the number of parameters. We believe that this is a World First in terms of a model based on real data with this quality of fit.

Further advantages of the model's parameters are that they can all be determined in advance of the software being created, and that there is little room for uncertainty and thus confusion.

We established links with over 50 MoD software projects. We want this to continue and develop so that we can improve the model and expand the coverage into new areas.

In a wider context, we would like to test the model in NATO and PfP nations against their projects, and where possible perhaps to share data. We would welcome any contact from defence staff or manufacturers to help us here.

For the future, we intend to make the model available to a wider population via the Internet. We want to extend its application into other areas outside defence where software is used under similar operational demands.

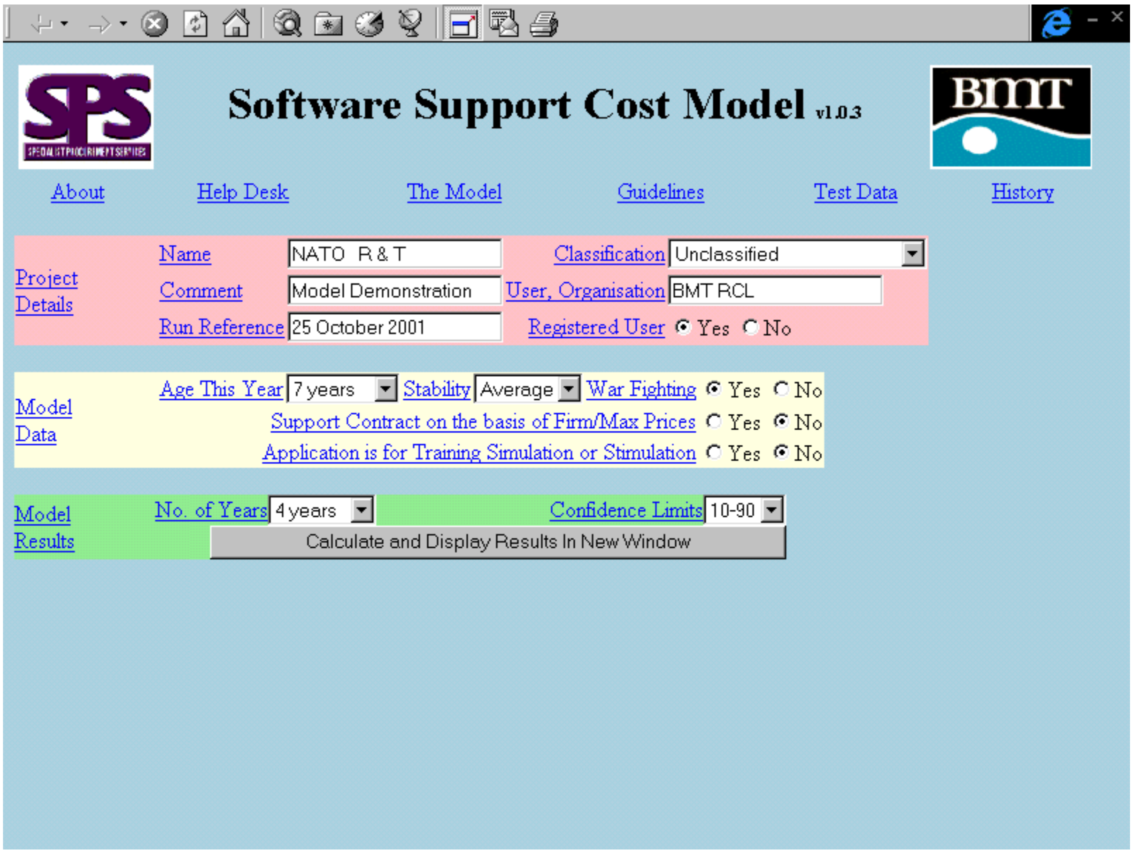
The success of the project has been in no small part due to the support and encouragement which we have received from our MoD sponsors in Specialist Procurement Services. We look forward to further development and application of the model both inside and outside defence. In terms of building an understanding of the Life Cycle Cost of Software Support, we have now seen and modelled more than just the tip of the iceberg.

Paper prepared and presented by:
Julian Gibbs, BSc, DMS, MIMgt
Principal Consultant, Whole Life Economics
BMT Reliability Consultants Ltd
12 Little Park Farm Road
Fareham, Hampshire
UK, PO15 5SU

tel: +44 (0) 1489 55 31 00
fax: +44 (0) 1489 55 31 01
email: julian.gibbs@bmtrcl.com
web: www.bmtrcl.com

MoD Contact:
Dr Dave Thombs, SPS/CF/Software, Abbey Wood
Bristol, UK, BS34 8JH

tel: +44 (0) 1179 13 27 54
fax: +44 (0) 1179 13 29 22
email: sps-cf-software@dpa.mod.uk



Software Support Costs for NATO R & T - Microsoft Internet Explorer

Unclassified *Unclassified* *Unclassified*

Software Support Costs for NATO R & T

Model Data	
Stability	Average
Age This Year	7
War Fighting	Yes

Cost (to nearest £000) in current year values

Year	FY	Low(10%)	Point	High(90%)
7	2001	£485000	£1303000	£3502000
8	2002	£495000	£1329000	£3568000
9	2003	£493000	£1323000	£3546000
10	2004	£483000	£1294000	£3465000

Generated from SSCM 1.0.3 at 18:24:16 on Thu Sep 6 2001 by BMT RCL. (reference: 25 October 2001)
Model Demonstration

Printing Saving Results Graph Plots Sensitivity Analysis Calculated Costs

Unclassified *Unclassified* *Unclassified*

This page has been deliberately left blank

Page intentionnellement blanche

Click here to view PowerPoint presentation; Press Esc to exit

Life Cycle Cost Procurement Techniques

Maj. Altan ÖZKİL (MS in OR)
Turkish General Staff Headquarters
Scientific Decision Support Center
06100 Bakanlıklar, Ankara, Turkey

Introduction

The primary purpose of this presentation is to describe the nature of a spectrum of currently identified types of life cycle cost procurement techniques. These techniques have the common characteristic that all are designed to motivate contractors to design, manufacture and deliver equipment with lower life cycle costs.

You may believe that savings may be in the acquisition cost component of life cycle costs. However, primary emphasis is generally on reducing and controlling operating and support costs by transferring more responsibility to the contractor for equipment operating and support cost performance.

Spectrum of LCC Procurement Techniques

It has been found that life cycle cost procurement provisions must be individually tailored to each program to properly transfer the appropriate amount of responsibility for Operating and Support costs to the contractor. This has resulted in the development of a spectrum of LCC procurement techniques

The currently identified LCC procurement techniques including a variety of LCC incentive provisions are;

- Source Selection Criteria,
- Pre-award Testing,
- Design To Cost / LCC Design Trade Study Requirements,
- Reliability and Maintainability Acceptance Criteria

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

- LCC Incentive Provisions,
  - Award Fee,
  - Reliability Improvement Warranty (RIW),
    - RIW with MTBF Guarantee,
    - Reliability Demonstration Incentive,
    - Fixed Price Repair with Incentive,
    - Design to Cost Incentive,
    - Value Engineering Incentive,

All of the LCC incentive provisions listed above involve contractual language where a contractor can expect his profits to be affected by how well he succeeds in designing and delivering a product with low life cycle cost characteristics. Source Selection Criteria and Pre award Testing techniques deal with actions that can be taken to select contractors whose products should have lower life cycle costs, but do not involve incentives tied to 0&S cost performance. The third and fourth LCC procurement techniques deal with specific O&S cost objectives which must be met, and there is no incentive to improve the contract or product performance beyond that specified in these techniques.

Factors For The Selection of Appropriate LCC Procurement Techniques

There are many factors for the selection of LCC procurement technique or combinations of techniques would be most appropriate for any particular program. They include many program and design factors that can affect the future operating and support costs and how well these costs can be predicted at contract award.

Factors which can cause uncertainty about, what future operating and support costs will be, are important for the selection of appropriate LCC Procurement Techniques. These are;

- High performance requirements relative to current equipment,
- A tight development schedule,

- Limitations on funds for development and testing,
- Mission changes,
- Design to cost acquisition goals,
- Employment or operations and maintenance concept,
- Support personnel efficiency,
- Training efficiency,
- Quality control efficiency,
- Detail design decisions,
- Support equipment design and use,
- Training material quality.

When uncertainty is great in areas outside the contractor's control, techniques that place less responsibility and risk on the contractor, such as award fee and value engineering incentive provisions may be more appropriate. On the other hand if there is considerable experience with similar equipment and uncertainty results primarily from things such as design and quality control, over which the contractor has significant control, more demanding incentive provisions, such as a Support Cost Guarantee (SCG), Reliability Improvement Warranty (RIW) or RIW with an MTBF Guarantee are applicable.

Source Selection Criteria

Life cycle costing objectives may be achieved by making life cycle cost an important source selection criterion in procurements, which may or may not use life cycle cost procurement incentive provisions. These two approaches are complementary in that use of life cycle cost as a source selection criterion motivates a contractor to consider life cycle costs prior to source selection, and use of incentive provisions motivates a contractor to consider life cycle costs after contract award. The joint use of these two techniques also motivates contractors to submit realistic 0&S cost estimates at source selection because incentives will be tied to them.

Pre-award Testing

This is a procurement approach to reducing life cycle costs, primarily characterized by testing to assess important life cycle cost related characteristics prior to source selection.

The contract is awarded based on demonstrated LCC related performance in pre award testing. Pre-contract award tests are conducted to assess the LCC related equipment characteristics of each contractor's equipments, and the results of these assessments expressed in terms of life cycle costs, are used as the primary basis for source selection.

The advantages of pre-award testing are as follows:

- The source selection is based on facts concerning performance of equipment, not on promises.
- It does not require development and operation of a post-award measurement system to accurately verify the operating and support cost performance of the equipment in the field.
- It motivates contractors to innovate lower life cycle cost designs while they are still in competition with each other to get the prime development and production contract.

The disadvantages of pre-award testing are as follows:

- Because of the uncertainties involved, it is sometimes difficult for the Government and contractor to agree on a practical measurement system, which will equitably assess the 0&S cost performance of the equipment
- It does not motivate the contractor to further reduce the life cycle costs of his equipment after contract award.
- Its limitation to equipment procurements where it is feasible to buy and test equipments from competing vendors prior to making a source selection decision.

There are two major steps in applying this type of life cycle cost provision. The first major step is appropriate selection of candidate equipments. The second major step is the development of testing and source selection procedures and criteria.

Design to Cost/Life Cycle Cost Design Trade Study Requirements

This technique requires that contractor conduct studies to assess the cost implication of design and support alternatives.

Design trade studies are a common requirement on most development programs. The overall process of implementing this approach includes requesting offers to propose design to cost/life cycle cost (DTC/LCC) design trade studies, evaluating these proposals, and contracting for specific trade studies.

This technique for reducing life cycle costs can almost always be applied. In fact, where technology and other uncertainties make it difficult to transfer responsibility for O&S cost performance to contractors, this approach may prove most advantageous. It also promotes the engagement of government personnel in design decisions affecting 0&S costs.

This approach does not contractually make the contractor responsible for O&S cost performance as demonstrated in the field.

The methodology for the application of this technique is defined as follows:

- Determination of adequate time and design flexibility,
- Determine whether the DTC/LCC design trade studies to be involved should be specified by the Government, proposed by the contractors or both,
- Describe all required DTC/LCC design trade studies for the contractor,
- Evaluate the proposals with respect to the DTC/LCC design trade study plans presented by each contractor.

- Include in the contract Statement of Work a required list of specific trade studies, any requirements for additional trade studies, and documentation requirements for all trade studies conducted.
- Assure appropriate Government design specialists and other necessary personnel monitor the contractor's work to evolve a low life cycle cost system or equipment design.

Reliability and Maintainability (R&M) Acceptance Criteria

This is the technique used to motivate contractors to produce equipment with low O&S cost characteristics requiring reliability and maintainability demonstration tests which have to be passed before equipment is to be accepted under the contract.

This technique has been adapted as necessary for individual programs. Using reliability acceptance criteria as an example, its essential elements are;

- Minimum acceptable mean time between failure (MTBF),
- Specification of environmental and other test conditions,
- Specification of acceptance test criteria, such as sampling plans, test time, failure definitions,
- Conducting the tests and arriving at a decision to accept or reject based on the results,
- In case of rejection, redesigning the equipment and repeating the tests until achieving the results required for acceptance of the equipment.

This technique is a well-defined procedure and involves little or none of the uncertainty with respect to how equipment will be used in the field in the future that complicates other LCC procurement procedures. In addition, this approach separates development and support activities somewhat simplifying its planning and execution.

The basic disadvantage of this approach is that successful laboratory testing is a necessary but not a sufficient guarantee that the equipment will demonstrate

acceptable reliability in the field. It is difficult to design a test procedure, which will correlate MTBF values observed during the tests to those expected in the field.

From an incentive standpoint, this approach is deficient in that it does not give the contractor any incentive to design the equipment any better than necessary to meet minimum reliability criteria.

LCC Procurement Incentive Provisions

General

The contract provisions designed to motivate a contractor to deliver lower life cycle cost systems or equipment are called as LCC Procurement Incentive Provisions. Cost reductions may be sought in support costs, acquisition costs or both. The eight types of provisions represent a spectrum of approaches, which can be used individually or in combination to match the LCC reduction motivation needs of new programs.

Award Fee

The objective of using the award fee is to motivate the contractor to take action to engage in one or more activity areas, such as design trade studies, more extensive or efficient testing, resulting in eventual life cycle cost reductions. The two essential parts of all award fee provisions are the maximum size of the fee and the criteria to be used by the Government in making a determination on how much of the maximum possible fee to award. The criteria are very important in that they communicate to the contractor what should be accomplished to earn an award fee.

The primary advantage of life cycle cost award fee incentive provisions is to provide a mechanism for evaluation of contractor management, which usually received secretarial review. An award fee determinations made at some time in the future can be based not only on evidence of the contractor's performance, but on additional

information bearing on the difficulty of achieving life cycle cost objectives, not known at the time of contract award.

Many feel and argue that award fee provisions, which do not hold contractors responsible for not delivering low life cycle cost equipment, as promised, do not adequately motivate contractors. Since award fee provisions are primarily designed to reward a contractor for moving from expected performance to better than expected performance, they may not provide motivation with respect to improving equipment with poor LCC performance. In addition, maximum life cycle cost award fees are generally small compared to the potential operating and support cost reduction opportunities.

Support Cost Guarantee (SCG)

Support Cost Guarantee (SCG) provisions should generally be used in conjunction with firm fixed price contracts. Support cost guarantee provisions generally have both negative and positive features. When a positive incentive feature is employed, it is provided either as an award fee or price adjustment provision. The simplest type of price adjustment provision is to pay a higher price for items, which have lower support cost characteristics. The negative incentive feature usually takes the form of one or more of the following type provisions:

- Hardware Correction of Deficiencies: A provision by which the contractor guarantees that support costs will meet a given target value as demonstrated by verification testing, and that he will correct deficiencies causing this value to be exceeded.
- Downward Price Adjustment: A provision similar to the hardware correction of deficiencies provision except that the remedy for exceeding the support cost target is a negotiated downward price adjustment either through a reduced fee or a reduced price for a specific production quantity. The schedule for such downward price adjustments must be included in the contract.
- No Cost Additional Spares: A provision also similar to the hardware correction of deficiencies provision except that the remedy for exceeding the

support cost target is that the contractor provides, at no additional cost, additional spares to offset the support cost deficiency.

- Ceiling price for Repair: During the period of time required to develop support equipment and data, the contractor can act as the depot and accomplish repair for a unit price per repair. Given a time period, a fixed usage rate and a predictable return rate, a ceiling of the repair cost can limit the cost obligation to the Government.

Contractor commitments to keep support costs below a specified level are established in the contract. Objective and realistic support cost estimates must be made early in the program. The contractor's design effort is forced to direct attention to the supportability of the equipment through the design process.

Extensive field verification tests involving training, using, acquiring and supporting command personnel are required. The time required to conduct this test may defer contract settlement, closeout, or payment. The expense associated with field verification testing is great and the administrative tasks are many; however, limiting the negative incentive to no cost additional spares can limit the testing to measuring MTBF only.

Reliability Improvement Warranty (RIW)

The objective of an RIW is to motivate contractors to design and produce equipment that will have a low failure rate, as well as low repair costs after failure, resulting from operational use. In general, an RIW will provide for the repair or replacement of failed units as well as agreed to no cost engineering changes and the associated calibration, adjustment and testing. RIW is not, however, a maintenance contract, and RTW provisions will not require a contractor to provide routine periodic upkeep, i.e., adjusting, cleaning, and replacing fuses or light bulbs.

Under RIW, the contractor has a degree of financial responsibility for field performance of his hardware. The contractor no longer may seek lowest acceptable

reliability. The contractor achieves maximum profit by controlling and making appropriate tradeoffs between production costs and certain operating and support costs.

The Government can defer many initial logistics decisions concerning the purchase of spare parts, test equipment and technical data. These decisions can then be made based upon more and better information generated during RIW.

When an RIW approach is properly considered early in development, support cost risks are surfaced at a time when they can best be addressed and costs avoided. The disadvantages of this provision are;

- It may not be practical to estimate with any degree of accuracy the warranty costs for many new items of equipment having any significant technical complexity.
- Laboratory controlled reliability demonstration tests alone may not provide a sufficient basis for developing a reasonable estimate of expected field reliability and reliability growth potential.
- The most important fact affecting the economic outcomes of an RIW is the rate of return of units to the contractor's plant. A prediction of this actor must be based on known or estimable data in order to identify and control risk. This factor is significantly influenced by how the equipment will be used in the field.
- Use and environmental conditions must be clearly defined at the time of warranty pricing. This information is often not available. However, some uncertainty on use and environmental factors can be reduced through contractual provisions, e.g., adjustment for usage rate.

There are a number of other criteria that should be satisfied for an item to be selected for Reliability Improvement Warranty coverage

Reliability Improvement Warranty (RIW) with MTBF Guarantee

The objective of an RIW with an MTBF guarantee is to provide a life cycle cost control approach assuring the Government of obtaining the MTBF maturation through the guarantee provision. Projected MTBF maturation is contained in the contract as a function of time over the warranty period. If the specified operational MTBF is not achieved, the contractor is required to provide additional spares to support operations and may be required to submit corrective engineering change proposals and implement approved changes at his expense.

The contractor may be required to make his design, redesign and corrective action decisions so as to achieve his guaranteed MTBF. Therefore, the Government should get equipment with not only lower support costs but with increased mission reliability and. increased availability.

The final design configuration should be stable and the Statement of Work and specifications developed to provide the capability to define; measure and predict the MTBF and its growth during the warranty coverage. This is often not possible at the time when the acquisition is still in a competitive environment if only one full-scale development contractor is involved.

Reliability Demonstration Incentive

This is a procurement technique which includes a provision paying the contractor for a variable price per unit depending on the reliability of the equipment demonstrated under a specified set of test chamber conditions.

In a reliability demonstration incentive type of life cycle costing procurement, a bonus fee schedule will be prepared based on the reliability of the equipment demonstrated under specified conditions. This approach primarily differs from other life cycle cost incentive provisions in that the basis for incentive provision settlement

determinations is Government specified and closely monitored test chamber, not field, reliability demonstrating testing.

The primary advantage of this life cycle cost procurement technique is that it gets directly to the root of many operating and support cost problems, low reliability equipment. It has the advantage over some LCC procurement techniques in that it requires the demonstration and assessment of only one parameter, that is, equipment reliability as opposed to several parameters required to assess total equipment life cycle costs.

One disadvantage is that this incentive is tied only to reliability and does not include consideration of other factors which affect life cycle costs, such as time to repair, spares consumption, required maintenance skill levels, etc. Another disadvantage is that historically there has been poor correlation between reliability test results conducted at the contractor's facility and reliability demonstrated in the field. This approach cannot work effectively unless this problem is substantially corrected.

Fixed Price Repair with Incentive

The objective of a fixed priced repair incentive contract is to control support costs by obtaining unit repair cost prices in a competitive environment, and motivating the contractor to achieve the reliability used as a basis for the unit repair cost prices and the contract repair cost ceiling.

The Government can obtain fixed commitments on repair costs while suppliers are still in competition. Objectivity and realism in support cost estimates submitted for source selection consideration are enhanced. The contractor incurs a lower cost exposure risk than he might incur on an RIW contract.

There is no guarantee that reliable and maintainable equipment will be delivered. Contract repair often requires additional pipeline spares and the associated costs. There is less incentive for the contractor to improve the reliability of the

equipment than on RIW contracts. There may be time when forecasting the field reliability is difficult and therefore arriving at an equitable ceiling price may be difficult. Cost effective application of this approach is generally limited to items normally repaired at a depot and where the expense of the added pipeline spares costs are not prohibitive.

Design-to-Cost (DTC) Incentives

An incentive arrangement used to motivate the contractor to introduce producibility and supportability considerations into his design, suggest configuration changes which can reduce cost without seriously reducing mission performance capabilities, and to recommend the elimination of performance requirements or specifications which do not provide system capabilities commensurate with their costs.

Currently most design to cost targets are tied to production costs. A design to cost incentive in a production contract is a fixed priced incentive agreement generally using specified formulae for establishing the earned level of profit. The formula would base the target profit on the achievement of the specified design to cost target. The formula may have positive and negative incentive features. It is applicable to design to cost targets that can be quantified and measured, such as a unit or cumulative average unit production cost target for a specified buy quantity produced at a specified rate per month.

A design to cost incentive can increase contractor's profits while decreasing Government costs. An innovative contractor should be able to achieve design to cost objectives without degrading performance. Use of DTC incentives can provide a means of motivating the contractor to reduce costs when competition no longer exists. They also provide a means of cost control in procuring the first production quantities.

Control and visibility over non target related costs must be rigorously maintained to preclude actions reducing target related costs while increasing nontarget

related costs. This approach requires the continual tracking and assessing of the cost target, which will be affected by directed design changes, escalation and many other factors. When Government directed changes may impact the agreed to target, a new target must be negotiated in a noncompetitive environment.

Value Engineering Incentive

The objective of value engineering incentives is to encourage the contractor to submit cost reduction proposals involving some change in the contract specifications, purchase descriptions, or contract statement of work. This may include the elimination or modification of any requirements found to be in excess of actual needs in areas such as design of components, materials requirements, material processes, tolerances, packaging requirements, technical data requirements, or testing procedures and requirements.

Unlike several of the new types of life cycle cost provisions, value engineering incentive payments related to O&S cost reduction related proposals are based on estimated savings rather than field experience with the specific equipment.

Value engineering incentives in full-scale development contracts are one management tool for reducing production and operating and support costs. However, precautions must be exercised to prevent possible duplication between value engineering incentives and other life cycle cost incentives.

Value engineering provides a management mechanism and tools to motivate contractors to challenge unnecessary requirements and thereby reducing life cycle costs. This in turn can provide an opportunity to involve each manager, engineer, and technician in cost reduction activities as part of his responsibilities for meeting performance and schedule requirements.

Value engineering techniques can be applied to a wide range of programs. Prime contractors can use them to encourage subcontractors to reduce costs. Value

engineering provisions have a relatively short evaluation period prior to incentive payment thereby increasing the contractor's motivation.

Valid assessment of operating and support cost reduction implications of changes is often difficult and may involve considerable uncertainty. Value engineering may not be an adequately strong incentive to reduce future costs.

This page has been deliberately left blank

Page intentionnellement blanche

Click here to view PowerPoint presentation; Press Esc to exit

Expérience navale française nationale et en coopération concernant le LCC et le Cost Structuring

(Naval Experience Concerning LCC & Cost Structuring)

Patrice Garnier
DGA (délégation générale pour l'armement)
SPN/ST/MCO
8, bd. Victor, Paris, 00303
Armées, France

garnier.patrice@free.fr

Cette présentation vise à expliquer “ pourquoi ” (les demandes d’origine), “ comment ” (la démarche et le raisonnement) et les “ résultats réels obtenus ” (structure de coûts et perception par les utilisateurs étatiques et industriels) concernant une application de structuration des coûts dans un programme, puis ce qu’il en est advenu.

1. Origines du besoin

A l’origine de cette réflexion, se trouve le programme tri-national Horizon de frégates aériennes, dont la fiche de caractéristiques militaires (TSR = Tripartite Staff Requirements) comportait une exigence de maîtrise et de prévision des coûts relatifs à ces bâtiments.
De plus, l’une des nations participantes (UK MOD) posa le problème de la connaissance des coûts réels et des flux financiers liés aux différentes activités d’un bâtiment (savoir à quoi est employé l’argent) et de l’éventuelle budgétisation annuelle de ses coûts (de possession) tout au long de sa vie (réalisation + en service).

2. Traitement des demandes

Pour traiter cette double demande, différentes possibilités ont été passées en revue.

2.1. Généralités

* différence entre « structure » et « modèle »
En général :
Un « modèle » est une représentation dynamique ayant pour particularité que les modifications posées en entrée influent sur les résultats obtenus. Par suite, il est fortement dépendant (puisque représentatif) du système étudié. Il n’est donc pas transposable d’un système à un autre.
Une « structure » est une représentation figée (donc statique) de recueil et de synthèse des différents coûts générés par le système étudié. Il s’agit donc d’une représentation des coûts du système et non pas du système. Elle est donc, a priori, applicable à tous les systèmes.

* différence entre structure de bateau (ou de système) et structure de coût , en termes de coût.

Communication présentée lors du symposium RTO SAS sur les « Structures de coûts et coûts globaux de possession (LCC) pour systèmes militaires », organisé à Paris, France, du 24 au 25 octobre 2001, et éditée dans RTO-MP-096.

-La structure du bateau (ou du système) est en fait une structure du bateau représentée en éléments financiers :

Cost of the ship	B
➥–cost of the platform,	x
➥–cost of the combat system	y
➥–cost of the CMS	p
➥–cost of the AAW system	q
➥–cost of the ASW system	r

avec : $y = p + q + r$ et $B = x + y$

Cette approche est davantage adaptée à l'évaluation de l'acquisition d'un système.

-Une structure de (ou des) coûts du bateau (ou du système) est en fait une répartition des coûts aux différentes sources de coûts.
On peut ainsi identifier, comme source ou générateurs de coûts, des activités techniques, industrielles, managériales, d'emploi ou de soutien, etc. du bateau, d'une façon totalement indépendante de sa décomposition technique.
Cost of the system (through life)
➥–acquisition cost of the system,
➥–investment cost of the system,
➥–cost to operate the system,
➥–cost to support the system,
➥–cost to dispose of the system,

Chaque ligne peut-être détaillée, par exemple:
➥–cost to operate the system,
➥–cost of the manning,
➥–cost of the consumables
➥–cost of the fuel,
➥–cost of the ammunitions,
➥–cost of ..etc.

Cette approche est beaucoup plus proche du besoin de suivi des dépenses. De plus, elle peut-être appliquée à chaque élément de l'arborescence technique du système étudié.

- - -

2.2. Synthèse.

En fait, le problème posé est celui, déjà connu en comptabilité, de la connaissance des flux financiers, avec pour particularités, ici, d'être appliqué à un bâtiment, tout au long de sa vie, par le client et non par le fournisseur. Les pratiques comptables courantes des entreprises nomment cela de l'« information comptable » et le traitent par application des règles de la comptabilité analytique (à la différence de la comptabilité générale).

Puisqu'il s'agit d'un problème comptable, il faut tenir compte des différentes règles du métier et les adapter au problème.

On retiendra les éléments suivants pris aux différentes approches :

-a- Le plan comptable général français (PCG 82) permet de comparer toutes les sociétés, ici, tous les systèmes, grâce aux caractéristiques suivantes : présentation des coûts selon un formalisme obligatoire où chaque ligne de compte a un numéro et une définition claire de son contenu et de ses méthodes de calcul. De plus, chaque ligne est elle-même décomposée en sous-ligne autant de fois que cela est nécessaire à la précision voulue sur l'information de coût recherchée. Trois niveaux d'application (renforcé, basique, simplifié) sont utilisés en fonction de critères à définir et dépendant fortement du montant total et de l'importance de chaque ligne de compte.

-b- Composition des coûts (rappel) : Les devis industriels sont composés d'une somme de coûts directs : achats, surface, utilisation de ressources diverses (personnels, machines, etc.), essais, acceptation et de coûts indirects (management, commercial, etc.).
Des méthodes d'attribution des charges fixes existent donc et sont parfaitement applicables aux systèmes militaires.

-c- Approche « Investisseur » : Un « client » emploie ses *moyens financiers* pour obtenir un *résultat satisfaisant* en retour dont il veut maîtriser les aspects économiques.
Cela signifie qu'il veut :
- d'une part :
- - - du ROI (Return On Investment): C'est à dire qu'il veut vérifier que les montants financiers dépensés dans ce système X sont bien utilisés conformément à ses choix initiaux, et de préférence mieux que s'ils avaient été utilisés dans un autre système. Il veut donc vérifié qu'il ne s'est pas trompé dans ses choix.
- - - du ROA (Return On Assets) (aspect statique) : Le client veut vérifier que le système remplit ses obligations techniques (tenue des performances) dans les montants prévus.
- d'autre part : le client veut un contrôle de gestion (aspect dynamique) lui permettant de « tracer » ses dépenses.

-d- Approche Cycle de vie /besoin / logistique :
Le cycle de vie des systèmes est connu : les phases d'acquisition, exploitation et soutien, retrait. C'est celui qui sera utilisé pour cadencer le temps. Au sein de chaque phase, on pourrait diviser par année.
L'une des **principales difficultés** est d'identifier les « causes ou générateurs ou sources de coûts » pendant toute la vie du système. Pour cela, et compte tenu du fait qu'un système peut subir une ou des rénovations, on considère que toutes les causes initiales de dépenses subsistent potentiellement durant toute la vie du système, à l'exception des coûts initiaux non récurrents dont on considérera qu'ils concernent des éléments majeurs du système (ex : la coque) dont des modifications profondes correspondraient à un changement de système.

3. Comparaison et rapprochement des différentes approches

* convergence « générateurs de coûts » et « cycle de vie ou phases».
Cela conduit à une matrice des sources de coûts initiales en abscisses et des étapes du cycle de vie en ordonnées. Ainsi, des coûts d'études de « manning » apparaîtront dès l'origine (mise en service initiale, etc.) mais aussi plus tard au cas où la mise à bord d'un nouveau système nécessite à nouveau des dépenses pour ce type d'études.
Enfin, cette matrice s'appliquera de façon identique à tous les équipements du navire. La connaissance des coûts aux niveaux supérieurs sera obtenue par calcul et consolidation des lignes identiquement désignées de tous les équipements (inférieurs, donc) composant le niveau supérieur.

Le compromis final est donc une matrice «LCC/CBS» (Cost Breakdown Structure) de croisement des étapes du cycle de vie et de (toutes les) sources génératrices de coûts, qui sont donc ainsi conservées tout au long de la vie du système.
Cette matrice est composée de lignes de coûts clairement définis. Chaque ligne est identifiée part un numéro. Ce numéro n'est pas un simple numéro d'ordre mais le résultat de l'application d'une triple codification croisée, à la fois, de la période de temps d'application, de la source de coût et du type d'activités générant ce coût.

Exemple :

Code 1	Code 2	Code 3
Vie utile	training	études
2	- 5 4	2 0 -

Cette codification a volontairement été limitée à trois groupes de nombres pour ne pas alourdir son utilisation. Toutefois, cette limitation risquait de réduire ses capacités d'exploitation et donc l'information comptable disponible. Cette difficulté a été tournée en réutilisant les nombres inutilisés par les critères précédents.

L'ensemble des combinaisons des trois codifications est supposé couvrir toutes les opportunités de coûts.

Ainsi, peut-on distinguer :

Code 1	Code 2	Code 3
Système principal	Configuration	parc de systèmes
1	0 6 x	- 7 x
ou : munitions	Configuration	Management
8	0 6 x	0 1 x

Un autre avantage de cette codification est la possibilité d'utiliser directement les tables de codification pour attribuer un numéro à une ligne de coûts.

LCC/CBS n'est pas destiné à rapporter les coûts des systèmes pendant leurs seules phases de réalisations, mais durant toutes les phases de leur vie.

Enfin, une fois les coûts rapportés selon «LCC/CBS», les consolidations et calculs fournissent l'information comptable recherchée, grâce au collationnement des coûts concernés selon des critères de tris appliqués aux codes des lignes de coûts.

Exemples :

Toutes les lignes :	2	2xx	70x	fournissent les coûts initiaux dépensés pour le système de soutien du parc de système (commun à tous les systèmes).
Toutes les lignes :	x	22x	xxx	fournissent les coûts relatifs aux rechanges (initiaux et en service, études, communs au parc ou spécifiques à chaque système (après multiplication préalable par le nombre de systèmes), software et hardware (consommables et non),
alors que les lignes	x	223	xxx	fournissent idem limité aux softwares et sans les études.
et les lignes	x	x5x	xxx	fournissent les coûts liés aux facteurs humains :manning, training, , safety,etc.
et les lignes	x	x54	xxx	fournissent idem limité aux seuls aspects du training & training support.
et les lignes	2	054	xxx	fournissent idem limité au training & training support, durant la phase d'acquisition.

x = quelque soit le chiffre.

A bien retenir :

LCC/CBS est un moyen de collationner et rapporter
des *données de coûts* de n'importe quel *système* durant *toute sa vie,*
de les consolider avec d'autres coûts (du système supérieur),
de les comparer d'un système à l'autre, etc.

C'est une méthode reposant sur les règles fondamentales de la comptabilité analytique, ayant pour objectif de
savoir,
ensuite de
gérer,
pour *maîtriser*
les coûts de nos investissements
(durant toute leur vie).

Il en existe d'autres, bien sûr.
La difficulté était de trouver une traduction concrète et adaptée des règles de comptabilité analytique courantes, qui ont fait leurs preuves.
(Les tableaux des trois codifications sont donnés dans la présentation.)

4. LCC/CBS : situation actuelle.

Une fois le système conçu, le problème était de savoir comment il serait perçu, accueilli et finalement appliqué par les utilisateurs, et, en tout premier lieu, par ceux fournissant les informations de coûts.

LCC/CBS a été utilisé :
- sur le programme Horizon Tripartite (nations et industries), où les industriels en compétition, notamment, ont répondu aux appels d'offres en utilisant la structure,
- sur le programme français de Frégates Multi-Missions (FMM), pour améliorer l'identification des coûts disponibles et dans la prochaine phase de faisabilité,
- curieusement, il a été retrouvé sur des études ultérieures, alors que son emploi n'avait pas été imposé, ce qui signifie une sorte appropriation par certains industriels de l'ex-programme Hzn à des fins professionnels internes.

Qualité d'utilisation.
La qualité des réponses a beaucoup variée d'un utilisateurs à l'autre, toutefois, certaines erreurs ont des explications communes.
Les origines des difficultés rencontrées dans l'emploi de LCC/CBS ont été identifiées, il s'agit principalement :
- d'un manque de maturité des interlocuteurs industriels (ILS-M) en matière comptable et de gestion,
- de l'absence d'informations élémentaires de coûts au sein des nations.

5. LCC/ CBS : utilisation et exploitation.

Un minimum de rigueur est nécessaire pour utiliser LCC/CBS. Il s'agit d'appliquer certaines règles comptables et quelques directives d'emploi.

Les principales sont :

- déterminer le périmètre du chiffrage : quels systèmes, combien, points d'emplois (sur quels bâtiments), pour quelle période, etc. Le but est de savoir à quoi se rapportent les chiffres.

- déterminer, ou indiquer, les unités de chiffrage :
(a) quand le chiffre est fourni en unité monétaire : préciser laquelle, Franc, Euro, ou autres. Préciser s'il s'agit de (exemple) Franc « courant » (de tous les jours, en ce cas indiquer l'année) ou de Franc « constant » (ne tenant pas compte de l'érosion monétaire et/ou de l'inflation), ceci pour éviter de comparer des évaluations de 1980 à d'autres de l'an 2000,
(b) quand il n'est pas possible de réaliser le chiffrage en unité monétaire (exemple : lorsque l'industriel ne connaît pas le coût horaire d'un personnel du client), fournir alors les élément permettant le chiffrage, c'est à dire, généralement, l'évaluation en volume (ex : quantité d'homme*heure, etc.)

- enfin, se souvenir que les coûts fixes sont toujours imputables via l'utilisation d'une clé de répartition et d'unité d'œuvres comptables adaptés.

Une fois les chiffrages fournis, par l'industrie généralement,
- ajouter des informations complémentaires d'origine client (coûts élémentaires internes, exemple : coût d'homme*heure, coût de la tonne – ou litre- de carburant),

- réaliser les synthèses, re-calculs ou consolidations, via des tris à l'aide des numéros de lignes codifiées.

6. Améliorations ultérieures

- Renseignements des lignes de la structure.
Le but recherché étant l'information comptable, il est tentant de rechercher à accroître le nombre d'informations recueillies en multipliant les sous-lignes de comptes et/ou en détaillant le contenu des lignes sous la forme d'un devis industriel, par exemple (hommes, surface, ressources, etc..).
Toutefois, la rentabilité de cette possibilité est à comparer, à ce qu'elle pourra coûter (de la part des industriels, par exemple, pour lesquels cela correspond à un surcroît de travail, donc à un surcoût), d'une part, et au bénéfice réellement obtenu, d'autre part. En outre, le temps nécessaire au traitement des informations recueillies, par les organismes étatiques, est un facteur non négligeable qu'il faut considérer.

- Passage à un outil informatisé.
L'informatisation complète de la méthode de façon à bénéficier de consolidations et retraitements quasi-automatiques apparaît comme l'étape suivante. Elle est envisagée.

- - -

Click here to view PowerPoint presentation; Press Esc to exit

LCC Analysis for the Replacement of the Dutch F-16

Mr. R.C.T. de Haas, Mr. M.C. Smit
en Kol. Ir. M. de Zeeuw
Postbus 96864
2509 Den Haag
The Netherlands

Unfortunately Kol. de Zeeuw will not be able to attend the symposium, as in October 2001, it is expected that the project team will be very busy during that period in answering questions from parliament. However, the paper will be co-authored by TNO-FEL and RNLAF. And the RNLAF suggested that the presentation will be given by TNO-FEL.

Abstract:

In the presentation we will first describe the way LCC-analysis are performed in the Netherlands in a general way. In the Netherlands LCC-studies are mainly used in the acquisition process of new military equipment. Inside the armed forces a project team is responsible for the acquisition process and thus also for the execution of an LCC-study. TNO is also regularly involved for a number of reasons. The most important reason is that TNO is independent. Besides that TNO-FEL has developed a step by step approach for performing LCC-analyses inside the Defence Organisation, called FELSALDO. The FELSALDO method consists of five steps: planning, definition, development, analysis and report. We will show a common cost tree for the acquisition costs, the exploitation costs and the disposal costs. When the elements of the cost tree have been determined, these cost elements are estimated. There are different ways of estimating a cost element. After estimating the cost elements the total LCC can be calculated.

After this introduction we will focus on the project: Replacement F-16. We will show how the FELSALDO method was applied during the LCC-analysis in this project. First we will give a little background of the F-16 replacement project. We will indicate that LCC is only one of seven main decision criteria. After that we will give a detailed description of the LCC process, from planning to report using the five steps of the FELSALDO methodology. The LCC analysis in this project was done thoroughly and extensively. A lot of effort was put into gathering the right data from the vendors and a lot of interaction with the vendors was necessary in order to make sure that the data used was the right one and that the vendors data was used in an appropriate manner. Finally we will give the current status of the project, describe what the next LCC related problems will be and share the lessons learned of the F-16 replacement project.

Introduction

TNO is an independent contract research organisation (originated by law in the 19 thirties) consisting of 15 institutes active in a numerous areas of applied scientific research. **Defence** is one of the core areas. Three TNO institutes are working in the defence area with a total of around 1000 employees. One of them is the Physics and Electronics Laboratory (FEL).

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

LCC in general and FELSALDO

Organisation of LCC-studies in the Netherlands
In the Netherlands LCC-studies are mainly used in the acquisition process of new military equipment. Military equipment especially for the Army and Airforce is often procured Commercial Off the Shelf (COTS). Since 1993 LCC-studies are obliged in all stages of the Defence Materiel acquisition Process (DMP), that means for an acquisition project with a budget of at least fl. 5 million, an LCC-study has to be performed. Inside the armed forces a project team is responsible for the acquisition process and thus also for the execution of an LCC-study.

Involvement TNO-FEL ORB in LCC-studies in the Netherlands
TNO is regularly involved with LCC-analyses in acquisition projects for a number of reasons. The most important reason is that TNO is independent. Besides that TNO-FEL has developed a step by step approach for performing LCC-analyses inside the Defence Organisation, called FELSALDO. With this methodology project managers are able to perform LCC-studies themselves. But what we see is, that especially in the more complex acquisition projects TNO is invited to perform the LCC studies, most of the times in close co-operation with the project team. Our work consist mainly in composing or assisting in composing questionnaires on cost issues, that will be send to industry as part of the RFI, RFQ or RFP. When industry has answered these questions, the answers are evaluated, an LCC-analysis is performed and sensitivity analyses can be performed.

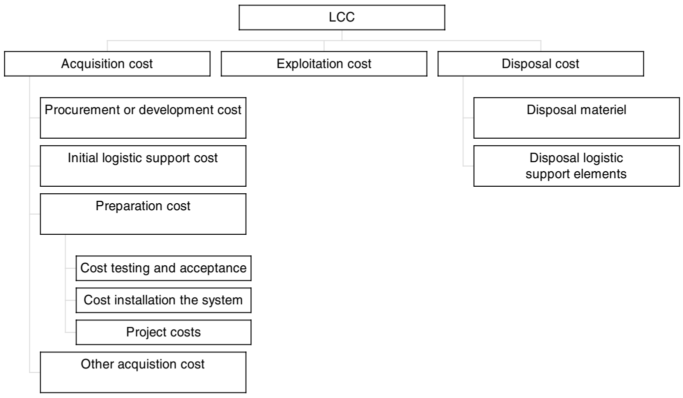
Especially in the more complex acquisition projects TNO is asked to support the armed forces in a broader way. TNO is able to provide support in a number of areas, like all kinds of technical, operational and logistic aspects. We have expertise in many areas. The project "replacement F-16" is an example of such a broad support.

Evaluating and reducing the initial and through life cost
The following type of LCC-studies can be performed in the acquisition phase of new equipment, the first one I mentioned already:

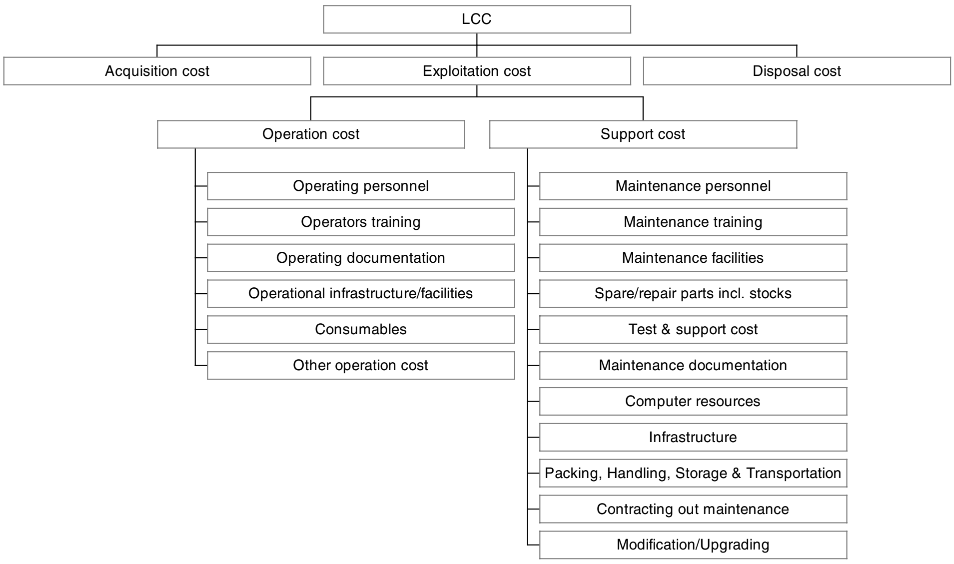
1. Estimation of the total costs for new equipment:
2. Comparison of Life Cycle Costs for different options to fulfil the requirements:
   Very often a number of candidate suppliers have to be compared in the acquisition phase. It is also possible that one candidate supplier offers a number of options to fulfil the requirements. The different candidate suppliers and the different options can be compared on cost issues, when a common cost tree is used.
   It is also possible to use LCC-analyses to calculate, evaluate and compare several support alternatives for the equipment. For instance a comparison of the concept of four levels of maintenance with the concept of two levels.
3. Determine important factors of influence / cost-drivers
   Cost-drivers are closely related with the main factors of influence. Based on the results of the study, cost-drivers can be analysed and studies can be performed trying to lower the total life cycle costs.
4. Sensitivity analyses on important factors of influence or uncertain cost elements
   When the important factors of influence are known, analyses can be performed on the sensitivity of these factors to determine their impact on the total life cycle cost. This type of sensitivity analyses can also be done on uncertain cost elements. On how to deal with uncertainty in cost I will come back later.

FELSALDO
TNO-FEL has developed a step-by-step methodology for executing an LCC-study. The FELSALDO method consists of five steps: planning, definition, development, analysis and report. The first two steps determine the objective and scope of the LCC analysis. The most important steps are the third and the fourth in which the LCC are calculated. Finally a report is written.

Here is an example of a common cost tree for the acquisition and disposal costs.



And an example of a common cost tree for the exploitation costs. If you examine the cost elements, you will recognise the various ILS-elements in this cost tree.



Methods for estimating the costs.
To be able to calculate the total Life Cycle Cost, cost elements have to be estimated. There are different ways of estimating a cost element. In one LCC-study different ways of estimating the cost will be used. The more detailed data is available the more accurate the costs can be estimated.

- For the analytical method mathematical expressions are used. This method requires a lot of information from the system considered. We try to use this method as much as possible in our studies.
- The parametric method is used when common CERs (Cost Estimating Relationship) are available using large historical databases. Only generic information on the system is required to calculate the costs.
- The method of analogy can be used if the cost of the new system can not be calculated, but when the cost of a similar system is known. Based on the cost of that similar system

the costs of the new system can be estimated, using characteristic parameters, technology factors and add-on factors.
- Three other methods can be used if even less information is available for the new system: expert opinions or rules of thumb may then help in estimating the cost. The method of simulation can be used if the real height of one or more cost elements is uncertain. Statistical methods (e.g. Monte Carlo simulation) can be used to produce confidence intervals for the total costs.

After estimating the cost elements, the total LCC can be calculated.

LCC in replacement F-16

Background of the project
The Royal Netherlands Airforce has the F-16 in service since 1979. Currently the RNLAF operates 138 AC form three main operating bases, Leeuwarden, Volkel and Twenthe. The F-16's have undergone a Mid-Life Update that is almost completed for the entire fleet. Around 2010 the aircraft has reached its operational and technical limits. The replacement of the F-16 is expected to take place in a time frame of 15 years (2010 –2025). The replacement of the F-16 is biggest NL material project ever, estimated at 10-12 billion guilders. For the acquitsition of material the Defence Material Procurement Process (DMP) is used. This process consist of five phases:
- DMP-A: determine the need
- DMP-B: preliminary study phase
- DMP-C: study-phase
- DMP-D: acquisition preparation phase
- DMP-E: evaluation

For the replacement of the F-16 the B and C phase are combined and this phase is almost completed. The reason that the B/C phase is done now, 10 years before introduction, is that experience learns that it takes 10 to 15 years to develop a new aircraft and that the RNLAF and the Dutch government is very interested in participating in the development of the replacement of the F-16 (this was also the case with the F-16).

The following timetable gives a broad overview of the replacement F-16 project:

Mid 1998:	Masterplan for project
End 1998:	Start of project
Beginning 1999:	Develop evaluation structure
Beginning 1999:	Formulating Request For Information (RFI) Sent out May 1999 Answers due October 1999
End 1999:	Start technical evaluation
Mid 2000:	End of technical evaluation, followed by further assessment by the RNLAF
End 2000:	B/C document formulated by RNLAF and presented to MOD and government (still not presented to parliament for approval)

For the replacement of the F-16 there are 7 main decision criteria of which LCC is one. Other main criteria are, for example, system effectiveness, risk and industrial participation. The following candidates were identified (through WEAG publication):
- Eurofighter Typhoon (EUR)
- Boeing F-18 E/F (USA)
- Saab Gripen (SW) (No LCC data)
- JSF (USA)
- Dassault Rafale (FR)
- Lockheed Martin F-16+ (USA)

Besides these candidates there were other considerations that were taken into account by the RNLAF:

- UAV's
- End-Life Update of the current F-16
- Continue flying with the current F-16

LCC was not used as a decision criteria for these alternatives.

LCC in the project replacement F-16
As stated earlier LCC was one of the main decision criteria. Expect for Gripen (no data supplied) an LCC analysis was performed for each of the candidates. Again we would like to stress that the focus is on the process and not on the results as they are still not made public.

First step of FEL-SALDO: Planning
Before the project started a masterplan for the whole project was formulated. The planning for the LCC analysis was part of this plan. The main purpose of the LCC analysis was to make a ranking for the main decision criteria LCC between the different candidates for the replacement of the F-16. It was also decided to make an estimation and evaluation of the exploitation costs (not investment costs) of the current F-16 in order to have a baseline for the comparison of the candidates.

Second step of FEL-SALDO: Definition
In the definition phase the system, its use and maintenance are described. The results of this phase were used as starting points and assumptions for the LCC-analysis. And this information was also included in the RFI.

Step three of FEL-SALDO: Development
The third and fourth step are the most important in the FEL-SALDO approach. The first step in the development phase is making a cost tree. Using the generic cost tree, a specific cost tree for the replacement of the F-16 was developed. Basically this meant that a few extra costs that were expected to be important such as simulator costs and costs for mission planning (systems) were added to the generic cost tree. The cost tree was used to determine who had to provide the cost information: industry or the RNLAF. For the cost elements that had to be provided by the industry detailed questions and definitions were formulated. LCC was a separate chapter in the RFI. The questions and definitions, together with the main assumptions such as number of flight hours, number of aircraft, personnel skills, etc, were included in the RFI.

After formulating the RFI a LCC analysis of the current F-16 was performed. Here only the exploitation costs were taken into account. These results were used as a baseline for comparison of the different candidates. The results were also used as the basis for the cost elements for which the RNLAF had to provide the information.

Step four of FEL-SALDO: Analysis
The answers to the RFI were due in october 99. The answers were first checked on completeness (were all questions answered) followed by a more thorough check of the contents. Points of attention were:

- Consistency with LCC assumptions
- Consistency with answers on logistics aspects
- Similarities and differences between candidates
- Similarities and differences with the current F-16

When answers were not clear additional questions were formulated and clarifications were given by industry. In some cases multiple question and answer sessions were necessary in order to get the right cost information. Also during this period formal presentations to the RNLAF were given by industry.

In this process a lot of information on the different cost elements was gathered. This information was used to determine the values of different cost elements. For a number of cost elements other experts were also consulted. The cost of fuel, based on flight hours and average fuel consumption per flight hour, for example were reviewed by experts on aircraft and jet engines. In a small number of cases information provided by industry were corrected or adjusted by the RNLAF. After filling in all the cost elements, the LCC of the different candidates were calculated.

In the whole process it became clear that the RNLAF and the various industries quite often used or interpreted the definitions of cost elements and information/data in a different way. The question and answer cycles reduced the misinterpretation a lot. To reduce misinterpretations as much as possible a final "verification" round was executed. The LCC project team visited the different industries to verify the LCC analysis. In this verification round the following things were done:

1. Check on the documents provided by industry
2. Show how the information on LCC was used in the LCC analysis
3. Show where and when adjustments were made
4. And finally show the results of the LCC analysis (the specific RNLAF information was excluded form this LCC analysis)

Also during this verification round the consistency between the configuration of the aircraft as presented in the operational/technical information and the LCC information was checked. The main reason for this was to make sure that the operational analysis and the LCC analysis were performed for the same aircraft.

As a result of this verification round a few minor adjustments were made the final determination of the LCC was done.

Step five of FEL-SALDO: Report
With the final analysis of the LCC ready it was time for the last step to make a report. The results of the LCC analysis were used by the RNLAF in their evaluation of the different candidates for the replacement of the F-16.

Current status replacement F-16 project
At the end of last year the RNLAF wrote the DMP B/C document, containing their evaluation of the different candidates for the replacement of the F-16. Early 2001 this document was presented to the MOD and the government. The MOD performed a formal validation of the evaluation and its results. So far the replacement of the F-16 has not yet been presented to parliament for approval.

Lessons learned
In such a big project there were obviously a lot of lessons learned. There is however one big lesson that we would like to emphasize: You have to make sure that, in big and complex projects like this, that the LCC projectteam and industry have to make sure they are talking the same (LCC) language. Using definitions and assumptions on LCC in general and on specific cost elements helped only partially in achieving this. The things that helped most to establish a clear understanding between the different parties were the formal presentations, the question and answer sessions and the verification round. This interaction between the RNLAF and industry created an atmosphere were mutual understanding on each others approach to LCC was achieved.

Application de modèles de coûts à un système de transmission

Marie-Pierre Pez
Ministère de la Défense
DGA/SPOTI
26, boulevard Victor
00457 Armées
France

marie-pierre.pez@dga.defense.gouv.fr

Emmanuel Arbaretier
Société SOFRETEN
10, avenue Entreprise Saint-Christophe
95865 Cergy Saint-Christophe
France

emmanuel_arbaretier@sofreten.fr

Sébastien Pierron
Société SOFRETEN
10, ave. de l'Entreprise
Parc St. Christophe
95860 Cergy St-Christophe
France

sebastien_pierron@sofreten.fr

1 RESUME

Cet article présente un cas d'utilisation de modèle de coûts dans le cadre d'un programme, où la notion de déploiement d'un grand nombre de systèmes sur plusieurs années est prépondérante, et est allé jusqu'à impacter l'organisation des études d'Analyse de Soutien Logistique : un premier concept SLI, initialisé lors de la fourniture du premier lot de systèmes et basé à la fois sur un profil d'emploi et une organisation de soutien étatiques donnés et sur des considérations globales du maître d'œuvre industriel en termes de disponibilité et de coût a donné lieu à des premières estimations de rechanges et de Maintien en Condition Opérationnel. Puis, à l'issue de la phase d'expérimentation terrain des premiers systèmes et, dans la perspective d'organisation du déploiement du parc complet et d'évolution de l'organisation de soutien associées, des analyses de disponibilité opérationnelle et de coût de soutien plus détaillées ont remis en question ces allocations initiales, et ont permis de réajuster les choix initiaux, dans une approche d'optimisation économique et d'Analyse de Niveaux de Réparation appliquée à la totalité du cycle de vie du système. Ce repositionnement des études ASL sur l'ensemble de la fourniture industrielle a permis d'identifier des gisements d'économie importants. L'article aborde également l'importance du facteur humain dans le processus d'appropriation de modèles ASL communs par des partenaires ne partageant pas a priori les mêmes intérêts : donneur d'ordre étatique, utilisateur étatique et fournisseur industriel.

2 INTRODUCTION

Le programme Valorisation RITA engagé par l'armée de terre vise le remplacement du système de transmission RITA 1ère génération et consiste en le déploiement d'un réseau tactique de près de 250 stations de transmission. L'objet du programme a consisté à développer et mettre en œuvre les composantes de cette nouvelle génération nécessaires à la satisfaction des besoins exprimés par l'armée de terre.

La phase de production a débuté en 1997 et doit se poursuivre jusqu'en 2007, année qui marquera la fin de la livraison à l'armée de terre du parc complet de stations Valorisation RITA. Ces stations seront livrées suivant un rythme de montée en charge progressive : le déploiement opérationnel, précédé d'une phase d'expérimentation terrain d'une durée de 2 ans, a été initialisé fin 2000. La phase de production comprend la production du système principal et de son système de soutien : la livraison des premières stations a été accompagnée de la livraison de l'ensemble des moyens permettant à l'utilisateur de soutenir un parc de 100 premières stations pendant les deux premières années de MCO.

Lors des études SLI concomitantes de l'ingénierie système de la phase de développement, l'industriel a proposé une politique de soutien et des évaluations globales de coût permettant d'ajuster les postes MCO des

Communication présentée lors du symposium RTO SAS sur les « Structures de coûts et coûts globaux de possession (LCC) pour systèmes militaires », organisé à Paris, France, du 24 au 25 octobre 2001, et éditée dans RTO-MP-096.

deux premières années; dans la perspective de livraison des stations complémentaires, la DGA a mis en œuvre une activité de modélisation et d'analyse de coût lui permettant de réactualiser les quantités de rechanges et les postes MCO évalués par l'industriel et concernant les années suivantes de l'ensemble du cycle de vie du système.

3 LE SLI ET LES ETUDES DE COÛTS DANS LE PROGRAMME VALORITA

A l'issue des études d'ingénierie logistique qui lui étaient confiées dans le cadre de son contrat, l'industriel maître d'œuvre a proposé un système de soutien optimisé où il avait procédé, entre autres, à une première attribution des niveaux de maintenance. Associé à ce système de soutien, une mise à jour du coût global incluant l'enveloppe des coûts industriels correspondant au MCO sur la totalité du cycle de vie du système a été fournie par ce même industriel maître d'œuvre. Cette estimation « macroscopique » établie en début de programme devait servir de base au chiffrage du MCO long terme, faisant suite aux deux premières années de mise en service.

Suite à l'initialisation de cette politique de soutien par l'industriel, la DGA a mis en place un partenariat avec les industriels et les utilisateurs étatiques, lui permettant de conduire une nouvelle optimisation de cette politique de soutien, tenant compte notamment de l'évolution de l'organisation de soutien de l'armée de terre associée au déploiement du parc complet de stations.

L'engagement de ce processus SLI a conduit entre autres à la mise à jour des exigences relatives à :
- la fourniture de données 1388-2B compatibles du système SIMAT (Système d'Information de Maintenance de l'Armée de Terre) prenant en compte, entre autres, l'intégration des données de conception du système, afin de permettre l'optimisation de son soutien en utilisation : MTBF, tâches de maintenance, nombre de personnels affectés aux différentes tâches. A noter que l'obtention d'un retour d'expérience significatif sur les différents éléments du parc de systèmes devra néanmoins attendre un certain nombre d'années.
- la mise en œuvre d'un système de gestion du ravitaillement compatible avec la norme AECMA 2000M

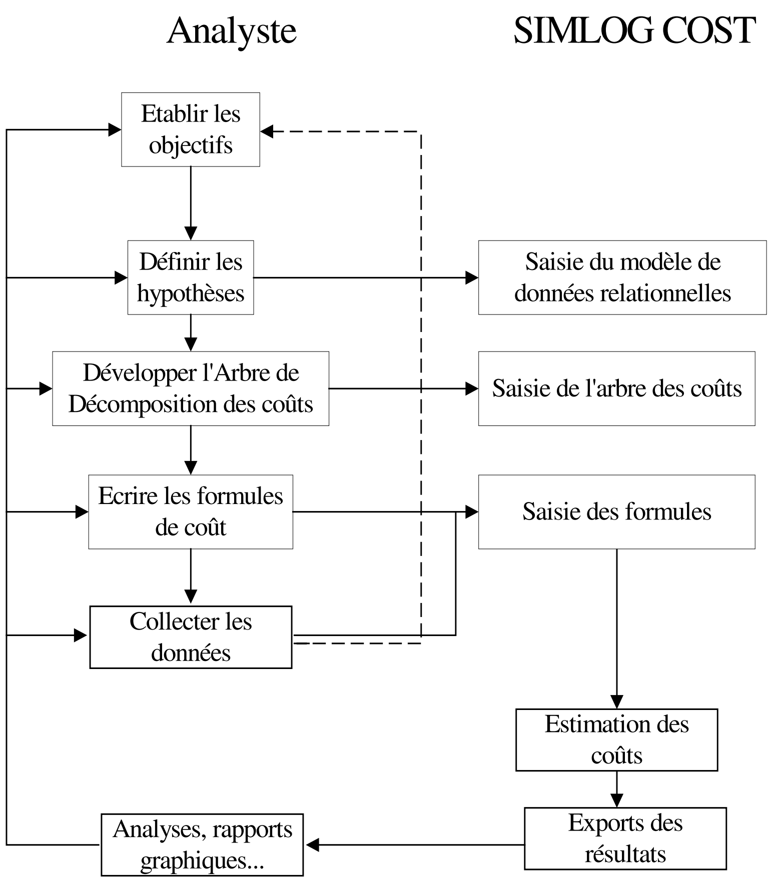
Dans le cadre de ce processus SLI, dont l'objectif majeur demeure la maîtrise des coûts et la recherche du compromis optimal entre ce coût et le critère d'efficacité que constitue la disponibilité du système, des analyses de coûts ont été conduites. Deux objectifs essentiels étaient visés dans le cadre de cette Analyse de Soutien complémentaire :
- l'optimisation de la quantité de rechanges globale à déployer, en adoptant un critère d'optimisation permettant d'éviter un surdimensionnement des stocks; à cet égard, la disponibilité opérationnelle de chaque système a été préférée à la probabilité de non rupture de stocks des différents articles,
- la prévision des dépenses futures de la DGA incluant en particulier l'allocation des différents budgets de MCO (Maintien en Condition Opérationnel) à négocier avec l'industriel et qui doivent s'échelonner sur les années à venir.

Ces analyses ont été effectuées à partir de l'atelier de simulation « SIMLOG » (issu de l'atelier DIANA) de la société SOFRETEN, et ont nécessité la constitution de modèles concernant la description et la simulation des stations, de leur politique de soutien, et de la génération des coûts associés pendant la totalité de leur cycle de vie. La méthodologie de réalisation de ces modèles, et leur contenu sont présentés aux paragraphes §4 et §5.

4 METHODOLOGIE UTILISEE POUR LA REALISATION DU MODELE DE COÛTS

La méthodologie de construction de modèles de coûts appliquée dans le cadre de ce programme peut être schématisée par un organigramme, telle que le montre la figure 1.
Nous allons passer en revue chacune de ces étapes tout au long de ce paragraphe. Il faut également mentionner la nécessité d'utilisation d'outils logiciels susceptibles d'aider l'analyste dans la construction et l'utilisation de

son modèle de coûts : ces outils assistent l'analyste dans toutes les étapes de conception de son modèle et permettent de prendre en compte toutes les modifications qui pourraient être apportées au modèle. La figure suivante met en évidence les différentes tâches qui permettront à l'analyste de mettre en œuvre la méthodologie de conception de modèles de coûts à partir du progiciel SIMLOG COST (distribué par la société SOFRETEN) qui a également été utilisé dans le cadre de ce programme.



Il faut garder à l'esprit que la génération d'un modèle de coûts doit s'appuyer sur une véritable modélisation des systèmes opérationnels et du système de soutien associé, et non sur un simple modèle de données relationnel ne permettant pas de simuler ou d'évaluer l'ensemble des mécanismes (statiques ou dynamiques) décrivant ces deux systèmes (fonctionnement par rapport à une ou plusieurs missions opérationnelles requises, dysfonctionnements et défaillances, acheminement et mise à disposition des ressources logistiques...).

Les différentes phases pour la conception de notre modèle ont été les suivantes :

4.1 ETAPE 1 : identification des objectifs

L'utilisateur doit identifier, formuler et définir les objectifs de l'étude qui nécessite le développement d'un modèle de coûts. Suivant son utilisation, le modèle de coût aura des caractéristiques particulières. Ainsi, à tout moment ces objectifs vont influencer :

- le choix des éléments de la base de donnée, le modèle relationnel de donnée,
- la décomposition de l'arbre des coûts,
- les formules d'estimation des coûts.

Dans notre cas, compte tenu notamment de l'avancement du programme au moment du lancement de l'étude, l'objectif premier était d'étudier les coûts liés à la maintenance, qu'elle soit préventive ou corrective. La structure des coûts a donc été définie en conséquence pour mettre en évidence ces différents paramètres influant sur le coût de soutien.

4.2 ETAPE 2 : définition des hypothèses

L'analyste doit identifier et adopter certaines hypothèses qui influencent le processus d'estimation du coût et qui permettent de mettre en place le modèle de données relationnelles. Ces hypothèses permettent de limiter l'analyse.

Les hypothèses doivent être claires et validées. Pour ne citer que les plus importantes, nous avons considéré les hypothèses concernées par :

- le nombre total de systèmes à concevoir,
- le taux de production du système et le programme de livraison,
- le concept d'utilisation du système,
- le concept de soutien logistique (stratégies de réparation niveaux de stocks requis, politique de maintenance…),
- la vie opérationnelle du système,
- la mise au rebut en fin de vie du système.

4.3 ETAPE 3 : spécification de l'arbre des coûts

L'analyste de coût doit structurer et formaliser les éléments de coût à estimer. Pour cela, il développe un Arbre de Décomposition des Coûts ('Cost Breakdown Structure').

Le but de cette structure arborescente a été de :

- prendre en considération tous les coûts
- ne pas comptabiliser plusieurs fois le même coût.
- rendre cohérents et définir clairement les éléments individuels de coût.

La structure de l'élément de coût a été organisée séquentiellement en quatre phases majeures du cycle de vie du programme, à savoir :

- l'acquisition (développement et production)
- l'exploitation
- le soutien
- le retrait de service.

Certains coûts comme les ceux relatifs à l'acquisition du système représentent des coûts constatés, d'autres comme les coûts de soutien et d'exploitation du système sont récurrents et ont été estimés à partir des hypothèses définies lors d'étape précédente.

4.4 ETAPE 4 : écriture des formules d'estimation du coût

L'écriture des formules d'estimation du coût consiste en la spécification réelle du modèle de coût; elle peut s'envisager suivant deux axes pratiquement mis en œuvre en parallèle, à travers un processus interactif. Il s'agit :

- de la spécification du modèle de données relationnel sous-tendant le modèle de coûts
- de la formalisation des liens logiques et analytiques (simples liens de dépendance logiques ou formules opératoires permettant de déduire certaines données à partir de données déjà existantes dont elles dépendent).

La spécification du modèle de données relationnel consiste en la description des structures de données élémentaires et non-élementaires sous-tendant le modèle de coûts. Par exemple, les articles constituant le système Valorisation RITA, les sites (opérationnels ou de soutien) tout comme les personnels nécessaires à la maintenance ou a l'exploitation, les équipements de test, la documentation, la formation sont des données jouant un rôle privilégié dans l'étude de coûts qui a été menée. Les coûts liés à l'exploitation ont été associés aux sites opérationnels, ceux-ci regroupant l'ensemble des activités d'exploitation. D'autre part, les coûts liés à la maintenance du système ont été associés aux sites de maintenance, ceux-ci regroupant l'ensemble des activités de maintenance.

L'écriture des formules de coût est spécifique à chaque modèle de coûts : on ne peut pas utiliser de modèle standard pour des applications ou systèmes de nature différente. A travers ce type de tâche, on va retrouver la notion de :

- loi physique ou plutôt 'logistique' qui introduit des points communs d'un modèle à l'autre
- hypothèses financières
- niveau de détail de précision du modèle

Les exemples suivants de formules utilisées dans le cadre de l'études illustrent ces différents points :

✓ ***Formule des coûts de soutien des moyens de réparation NTI3 de l'armée de terre :***

Disposant d'un coût de nature forfaitaire pour l'acquisition des moyens NTI3, le soutien de ces moyens a pu être évalué de la manière suivante (après estimation d'un ratio moyen nécessaire au soutien récurrent de ces moyens spécifiques) :

ratio_acquisition_moyens_NTI3(site)*cout_acquisition_moyens_NTI3(site)

✓ ***Formule des coûts de maintenance corrective :***

En fonction de la nature des données d'entrée mises à notre disposition, la formule d'estimation pour la maintenance corrective d'un article est la suivante :

lambda_article(article) * MET_article(article) * cout_personnel(personnel) * 8760 * nombre_article_site(article,site)

avec :

lambda :	taux de défaillance de l'article (en h^{-1})
MET :	Mean Exchange Time, c'est à dire le temps moyen d'échange de l'article (en h)
cout_personnel :	taux horaire du personnel
8760 :	correspond au nombre d'heures en un an

nombre_article_site : nombre d'articles de même type sur un site

4.5 ETAPE 5 : collecte des données

Cette étape a été réalisée en parallèle de l'étape 4 décrite précédemment. En effet, la collecte des données permettant d'identifier rapidement la ***forme*** sous laquelle pouvaient être fournies les données a directement impacté l'écriture des formules de coûts. Il était en effet primordial d'adapter le modèle de coûts à la réalité de ce pouvait être collecté. Cela dit, cette phase ne précède pas l'écriture des formules puisqu'elle comporte également une importante partie consacrée à la collecte ***numérique*** des données.

La collecte des données représente presque **90%** du travail de conception d'un modèle de coût. On distingue cinq étapes dans le processus de collecte des données :

- identifier les sources potentielles de données (rapports, opinions et jugements d'experts, résultats de modèles de simulation, organisations extérieures, centres techniques d'information)
- développer des stratégies permettant d'exploiter ces informations
- obtenir des données disponibles
- classifier les données en terme d'incertitude et de fiabilité
- identifier les données manquantes et celles qui nécessitent des validations ou des remises à jours.

4.6 ETAPE 6 : exploitation du modèle de coûts et estimation des éléments de coût

Après que les données nécessaires aient été collectées et évaluées, l'estimation des divers éléments de coût peut être obtenue à partir des formules d'estimation du coût.
A la vue des résultats, l'analyste peut revenir sur l'une des 5 étapes précédentes afin de mener à bien son analyse. Il sera toujours possible d'affiner l'utilisation du modèle en fonction de l'expérience acquise lors de l'exploitation du système, et ainsi apporter les éléments qui permettront de particulariser ou d'optimiser de façon récurrente le système de soutien.

Il s'agit par exemple, de pouvoir évaluer chaque élément de coût du coût global. C'est à dire que pour n'importe quel type d'objet d'attache ou combinaison de ces objets d'attache que représentent, par exemple, une catégorie de personnel, un site ou un article, et pour toute période du cycle de vie du système, on doit pouvoir estimer un coût.

5 PRESENTATION DU MODELE DE COÛTS

Le processus de collecte des données décrit au paragraphe 4.5 s'est appliqué à différents stades de la construction de notre modèle de coûts et a concerné l'ensemble des intervenants étatiques et industriels.

Le processus de collecte des données qui a été réalisé auprès des intervenants étatiques a permis de dimensionner :

- la construction même de l'arborescence de coûts. En effet, la décomposition du coût global en coûts élémentaires (Cost Breakdown Structure) nécessite la connaissance des objectifs exacts de l'étude de coût (évaluation globale, étude comparative…) afin de déterminer quels coûts seront à évaluer, mais il est également nécessaire de savoir au préalable quelles rubriques de coûts seront susceptibles d'être renseignées en fonction des informations disponibles.
- la détermination du système de soutien (sites opérationnels NTI1, niveaux de maintenance NTI2 et 3…), ainsi que des délais logistiques associés (par exemple les TAT, qui représentent les temps moyens d'échange entre 2 sites consécutifs…)

Le processus de collecte des données qui a été réalisé auprès du maître d'œuvre industriel a été largement facilité par les outils logistiques issus des travaux de SLI réalisés au titre de l'ingénierie logistique du contrat (BASL notamment). Cela concerne :

- la collecte des données techniques : arborescence de décomposition physique, diagrammes de fiabilité. Les diagrammes de fiabilité permettent de représenter la logique de fonctionnement d'un article décomposable.
- la collecte des données de sûreté de fonctionnement, et en particulier de fiabilité avec les taux de défaillance λ des divers composants. Les valeurs de ces flux de panne ont été déterminées en tenant compte du profil de mission du système afin d'évaluer des « lambdas mission ». La formule suivante a été utilisée :

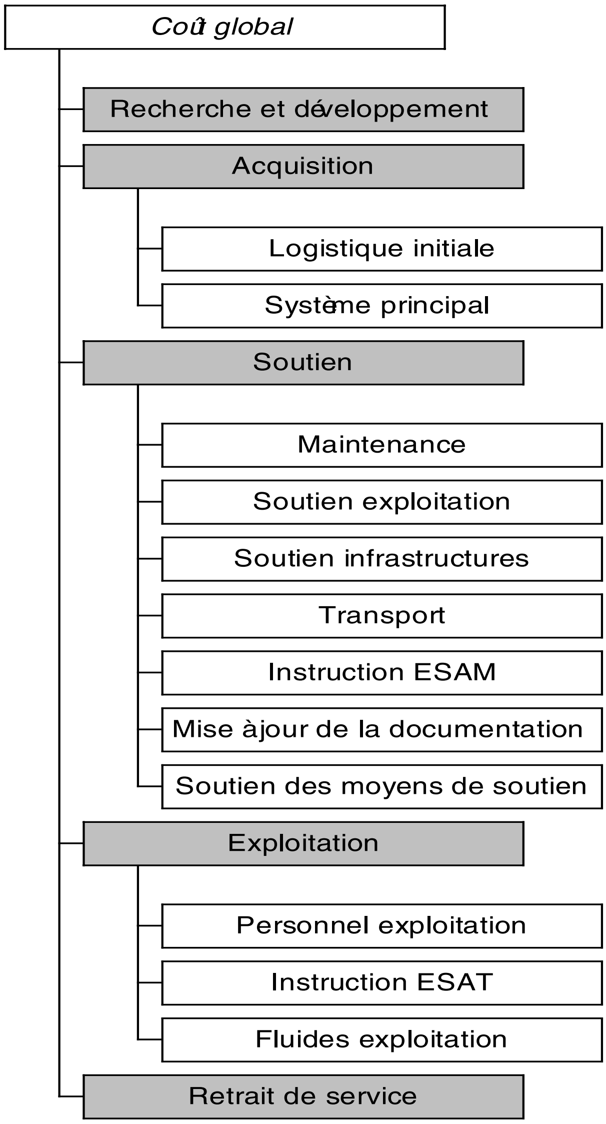
$$\lambda_{mission} = \frac{T_{fonctionnement\ sol\ fixe} * \lambda_{sol\ fixe} + T_{hors\ fonctionnement\ sol\ fixe} * \lambda_{hors\ sol\ fixe} + T_{hors\ fonctionnement\ sol\ mobile} * \lambda_{hors\ sol\ mobile}}{8760}$$

- la collecte des données logistiques et en particulier de maintenabilité, avec les temps de maintenance corrective MET (Mean Elapsed Time, correspondant au temps d'échange d'un élément (composant) par rapport à l'élément (composé) de niveau supérieur qui le contient), mais aussi les temps de maintenance préventive MPT (Mean Preventive Time).
- la détermination des politiques de soutien (niveaux d'échangeabilité, de stockabilité, et de réparabilité…), afin d'étudier les différentes variantes de rechanges impactant ainsi sur la disponibilité et le coût global du système. Pour le niveau de reparabilité NTI3, différentes alternatives ont été dimensionnées.

Ces données ont été présentées à la commission logistique intégrée regroupant l'ensemble des intervenants du programme et approuvées par celle-ci ; il est entendu qu'elles pourront être ajustées en fonction des enseignements qui seront tirés du retour d'expérience.

En ce qui concerne l'arborescence de coûts, la décomposition du coût global jusqu'au troisième niveau de coûts est décrite sur le schéma suivant :

Cost Breakdown Structure



Pour certaines rubriques de coûts, l'évaluation a tenu compte du planning d'approvisionnement de certains matériels et en particulier des dates d'acquisition des différentes stations décrites selon un échéancier particulier. En effet, l'ensemble des rubriques dépendant intrinsèquement du nombre de stations doit intégrer dans les formules de coûts certaines données permettant de traduire le déploiement d'acquisition de ces stations, traduisant ainsi la montée en puissance des coûts liés à l'acquisition du matériel.

D'autre part, cette projection du coût global sur l'axe des temps peut également être effectuée par rapport à d'autres critères de dépendance tels que les sites, les catégories de personnel…Ces différentes évaluations ont pour but d'expliquer les premières constatations obtenues par l'analyse globale, mais également de détecter des tendances, des valeurs de coûts marginales par rapport à certains axes d'étude et conduire à une optimisation toujours itérative du système de soutien.

6 PREMIERS ENSEIGNEMENTS ISSUS DE LA REALISATION ET DE L'EXPLOITATION DES MODELES DE COÛTS

La réalisation de ces modèles a privilégié un point de vue technique, à travers la déclinaison du concept de maintenance vis à vis des différentes composantes du soutien : le modèle de coûts obtenu traduira donc plus une représentation comptable du cycle de vie du système, en termes de flux de coûts générés, qu'une simulation contractuelle des différents lots de MCO tels que facturés par l'industriel et amortis financièrement par la DGA. C'est dans une phase ultérieure de collaboration entre l'adjoint logistique de programme et l'acheteur en charge des contrats MCO vis à vis des industriels, que ce modèle de coûts pourra être traduit en modèle de planification et de gestion financière.

La mise au point de ces modèles a nécessité le recueil d'informations techniques, organisationnelles et économiques qui s'est effectué tout au long du programme au sein de groupes de travail mixtes, réunis par la DGA, et rassemblant à la fois les industriels et les utilisateurs étatiques. Aucune contrainte de type budgétaire n'a été ressentie, aussi bien du côté industriel que du côté étatique; tout au plus certaines contraintes afférant au plan de charge des industriels, ont pu être à l'origine de quelques difficultés d'organisation des groupes de travail.

En fait, les données économiques recueillies dans le cadre de ces groupes de travail ont été fournies en grande partie par les industriels, les utilisateurs étatiques ayant un point de vue plus technique que financier. Il s'avère donc encore nécessaire de sensibiliser les étatiques à fournir ces données économiques concernant par exemple les taux horaires, les coûts de transfert, les bancs de maintenance, ou encore les règles d'amortissement proportionnel des différents types d'infrastructures (sites de stockage, ateliers de maintenance…). Ces dernières informations sont par ailleurs d'autant plus difficiles à identifier, qu'elles impliquent la connaissance des différents organismes qui partagent l'utilisation de ces infrastructures avec le programme, ainsi que la manière dont ils les utilisent : il s'agit alors de rentrer véritablement dans les règles de fonctionnement organisationnelles et financières de ces organismes, ainsi que dans leur logique d'imputation et d'amortissement proportionnel des différents programmes pour lesquels ils travaillent.

La modélisation des coûts de maintenance liés aux différents niveaux d'intervention a fait l'objet de difficultés différenciées : pour le NTI3, les approches ont été déclinées à partir d' études amonts ; pour les rubriques regroupant les coûts générés par le soutien des équipements de soutien, une approche sous forme de ratios d'expérience a été adoptée, ce qui traduit d'un point de vue méthodologique la nécessité d'adapter les formules d'évaluation au niveau de granularité des informations élémentaires susceptibles d'être recueillies.

Seulement un nombre limité d'hypothèses de prise en charge du NTI3 a été pris en compte :
- prise en charge par l'étatique,
- prise en charge par l'industriel,
- hypothèse mixte : en fonction de la tâche, en fonction de l'année, prise en charge par l'étatique ou l'industriel.

Cette limitation est atténuée par le fait que des analyses de sensibilité pourront être appliquées à la dernière hypothèse, en faisant varier le type de tâche affecté à l'industriel ou à l'étatique, ainsi que le planning des périodes de prise en charge du niveau NTI3 par l'industriel ou l'étatique.
Le niveau de maturité des industriels vis à vis des méthodologies de type SLI n'a pas posé de problème : dans le cadre de ce programme, la DGA n'avait à faire qu'avec un interlocuteur industriel, le Maître d' Œuvre, impliqué depuis longtemps dans des processus SLI, et rompu à ses différentes techniques d'analyse.

Des limitations quant à la connaissance précise des évolutions techniques à termes du système et de sa maintenance ont rendu difficile l'extrapolation détaillée du cycle de vie de vingt ans auquel devait se conformer le modèle de coût : en effet, durant la totalité de ces vingt ans, de nombreux événements techniques sont susceptibles de se produire :
- rétrofit des stations,
- évolution des moyens de maintenance et des coûts associés,
- portage majeur tous les 6 ou 7 ans.

Néanmoins, cette dernière hypothèse, a été prise en compte dans l'un des cas de figure de LORA envisagé de sous-traitance intégrale de maintenance NTI3 à l'industriel.

En outre, au niveau des calculs de rechanges, les objectifs de disponibilité opérationnelle par station ont été considérés comme constants sur toutes les années du cycle de vie. Il est à envisager qu'un ou plusieurs autres systèmes de transmission viendront seconder le système étudié sur la fin de son cycle de vie, et que les objectifs de disponibilité opérationnelle pourront être moins exigeants sur cette période.

Enfin, « last but not least », le facteur humain a paru être l'enjeu principal de réussite des groupes de travail impliquant conjointement la DGA, les étatiques et surtout les industriels. Il a par exemple toujours été clair que l'un des objectifs de l'exploitation des informations fournies par les utilisateurs étatiques et industriels au sein de ces groupes consistait, entre autres, en l'optimisation du nombre de rechanges dans un environnement de soutien en évolution. Cet objectif, en contradiction avec les intérêts industriels, et souvent décrié par les utilisateurs étatiques, illustre un des nombreux motifs de réserves invoqués à propos de l'organisation de ces groupes de travail: la difficulté de concilier des intérêts contradictoires.
En fait, la clé du succès de ces groupes de travail réside en un véritable effort de communication permettant aux industriels de s'approprier la logique « gagnant – gagnant » de ce type de partenariat : c'est la seule condition pour obtenir une attitude transparente et constructrice à travers une logique de coopération en complète synergie ; c'est l'occasion pour la DGA de véritablement optimiser l'utilisation de ses ressources humaines, techniques, et financières. Quant à l'industriel, c'est l'opportunité d'identifier de nouveaux gisements de profits, basés sur une prise en charge sélective et efficiente d'éléments de soutien du client, identifiés dans le cadre d'analyses conjointes, et anticipant les aléas coûteux du cycle de vie.

7 CONCLUSION

Les pilotes de coûts (« cost drivers »), identifiés dans le cadre de ce programme, ont été les suivants:

- dotation initiale de rechanges,
- maintenance NTI1,
- maintenance NTI2,
- maintenance NTI3,
- maintenance préventive,
- soutien des moyens de soutien.

Afin d'introduire une véritable dynamique d'optimisation de ces éléments de coût de soutien, il a été nécessaire de veiller attentivement à :

- l'obtention de la fiabilité intrinsèque de chaque équipement,
- une estimation réaliste des différents délais de transport et de réparation,
- l'optimisation de l'organisation logistique à travers la mise en commun des ressources et l'attribution des niveaux de réparations, article par article,
- l'allocation des informations élémentaires de coûts.

Mais plus que des difficultés purement techniques qu'il est finalement toujours possible de traiter, soit à travers une connaissance précise des informations, soit à travers des démarches d'allocations ou encore par analogie ou exploitation d'un retour d'expérience, c'est l'instauration d'une véritable logique de partenariat MCO avec des industriels et des utilisateurs étatiques, basée sur une stratégie « gagnant-gagnant » et permettant des analyses LORA élaborées, qui constitue le véritable enjeu de la démarche de Soutien Logistique Intégré.

This page has been deliberately left blank

Page intentionnellement blanche

Click here to view PowerPoint presentation; Press Esc to exit

Monolith Composite Structures - Trend for Creation Low Life Cycle Cost Airframes

Nodar W. Pkhaladze, and Giorgi O. Rusiashvili
Flight Problems R&D Society of Georgia
380060, Gamsakhurdia ave. 28, Tbilisi, Georgia
E-mail: nodar@kheta.ge; giorgirus@hotmail.com

ABSTRACT

Principles of creation Low Life Cycle Cost monolith integral composite airframes for military application by new technological approach are presented. New technological approach including airframe fabrication in whole opening self-heating press from by Resin Film Infusion process is offered. Typical technological process including the operations and transitions are described. Impact of new technological approach to design principles is discussed. Bases of Low Life Cycle Cost economical analysis for creation airframes by high technological efficiency are presented. Recent achievements enabling performing of new technological approach are summarized.

KEYWORDS: Low Life Cycle Cost, Monolith Integral Composite Airframe, Resin Film Infusion, Self Heating Press form.

INTRODUCTION

Since the 50^{th}, when organic composite materials were originally used in warship construction, material manufacturers got enough experience in developing resin matrix and fiber components with high mechanical properties, durability and damage tolerance characteristic. Main reason, which serves for widest application of organic composite in aircraft manufacturing till recently was an excellent specific weight ratio of airframe structures. Now, after significant establishment of composite in aircraft manufacturing (40-70 % of structural weight of combat aircraft and rotorcraft, 20-40% of commercial and transport planes, and nearly 100% new generation general aviation aircrafts), the material suppliers and aircraft designers and manufacturers have to solve the following very important problems:

How to reduce material costs and develop the new perfect structures and manufacturing technologies using which will be possible an output of Low Life Cycle Cost airframes?

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

One of main direction of them is to achieve of large-scale integration of airframes components till to develop of monolithic structures by combination of manufacturing and assembly works. Fortunately, such of opportunity gives composite, because composite materials are produced at the same time as the piece and gives possibility easy produce large structures with complex geometry and modify locally their properties by choose with the composition of the materials. Furthermore, special nature of composite structures makes permissible to insert any other functional elements into structures at the same time of processing of airframes. Therefore, we will look in nearest future the new advanced technology and design development by with market will revise the perfect low cost composite airframes.

TASK AND APPROACH

Targeted to development Low Life Cycle Cost airframes manufacturing technology for military application special emphasis would be lay on hardly estimated links between structural and fabrication features of airframes and economical benefits, which potentially will be achieved by application of some of solution in order of serial manufacturing. Low Life Cycle Cost mainly means Low Cost fabrication technology, because most of expenses spended on design, manufacturing and utilisation phases of life cycle of aircraft takes manufacturing phase and it is nearly 80% of total. As for manufacturing phases, approximately depending on process used, carbon fiber epoxy resin composite structures takes about 10% of the final cost, 40% gives material costs and 50% fabrication technology. Therefore, aviation industry is in need of cheep composite materials compatible with simple and cheep processing. Present paper discuses a direction of development simple and inexpensive manufacturing processes linked with airframe specific design.

The main questions, to be solved in order to develop such technology are:

1. To provide low cost serial manufacturing of high performance airframes of air vehicles;
2. To obtain whole compositional sandwich type, metal framework, foam filling in, integral shell by laying up fiber cloth in disconnection negative press form (mould);
3. To achieve high accuracy reproduction of airfoil shell (forms and dimensions);
4. To ensure high quality of airfoil shell surface;
5. To obtain light firm structure of high air flexibility, vibration and thermal insulation, fatigue resource;

6. To integrate in onetime technological cycle the manufacturing and assembling works;
7. To minimize the technological, construction and operational casing joint by its unification.

To achieve the objectives above mentioned, sandwich type, monolithic integral shell carrier structure with built in metal framework for airframes is offered; Also for manufacturing of those airframes, special structure press-form (mould) with built in heating devises for providing polymerization process of carbon-epoxy pesin composite by using Resin Film Infusion Technology and pneumatic bag methods is offered.

The results are elaboration of generic technological process and technological equipment for serial production of sandwich type, integral, high quality, light airframes of air vehicles by laying up fiber cloth in disconnecting press forms.

One of the most important directions ensuring low costs high reliable and greater resources for airfoil shell of light apparatus by minimum weight is making monolithic design with minimum constructive, technological and operational disjoin by using advanced constructive materials, specifically compositional materials, type glass or carbon fibers. Framework uses traditional metal materials type of aluminum or titanium.

The proposal of technological process for making outwardly and inwardly shell of glass or carbon fiber laid up in moulds with epoxy resin gives possibility for making a monolithic construction of high precision and high-quality surface three layer whole-compositional sandwich shell, with the high quality of air flexibility, vibration, noise and thermal insulation. It is characterized by high quality energy dissipation, effective, minimum technological disjoin and minimum weight.

Essence of the technology consists in forming double-skinned glass-fiber integral airframe sandwich construction with built-in metal framework in the disjoined negative mould, cut-off that corresponds to the perimeter (periphery) of the apparatus in the plan.

BASIC ECONOMICAL ANALYSIS

As known, economical effectiveness of flying apparatus namely airplanes as transport vehicles maybe shown by equation:

$$E=Cf/Ce=(VxGcxR)Co/(C1+C2+C3) \qquad (1)$$

where,

Cf- incomes on full term of exploitation of airplanes, USD;

Ce- total expenses on airplanes, USD;

V-an average velocity of airplanes, km/hr;

Gc- commercial load, tm;

R- technical resource of airplanes, hr;

Co - price for transportation USD/tm*km;

C1-expenses on design and development of experimental (pioneer) airplanes divided on the number of manufactured airplanes (N), USD;

C2-an average expenses for manufacturing of serial airplanes, USD;

C3-an average total expenses for exploitation and repair (maintenance) of airplanes on full term of exploitation, USD.

If admit, that C1 and C3 compose an about at 10% of each in total expenses, then becomes clear, that important role plays upgrading of technological efficiency of serial fabrication processes of aircraft, i.e. decrease of manufacturing expenses (denominator) in order of constant meaning of numerator.

As it is known economical efficiency of technological processes besides of others could be assessed by three enlarged parameters, which are:

1) Level of labor productivity,
2) Level of self cost of the production,
3) Efficiency of investments.

In the present paper will be discussed the approach to improving these meanings of efficiency of production of the airframe of flying apparatus from glass or carbide composite materials on the basis of new approach of creation of bases of technological process and relating methods of construction. The idea of the latter is in the maximally possible enlargement of aggregates of integral airframe till to creation of wholly monolithic composite shell and its production in one technological process by using a few operations and transitions.

All above indicated three enlarged parameters are functions of quantity of produced units, as increasing of volume of production enable introduction modern methods of production and maximally mechanize and automatize the process of production. Taking into account the fact that some types of military aviation products could be manufactured with high serially it could be concluded that increasing of the integrity and monolith of aggregates

(parts) of airframe would lead to decreasing of total technological cost of unit, which could be expressed by the following equilibrium:

$$Ct=Cm+Cw+Cue+Cse/N+H \qquad (2)$$

where,

Cm – cost of materials, used on manufacturing of unit, USD;

Cw – salaries and wages of labor on manufacturing of unit, USD;

Cue – expenses on depreciation of universal technological equipment, USD;

Cse – expenses on depreciation of specific technological equipment, USD;

N- number of manufactured units;

H – all contingencies related to realization of technological process, USD.

Analyzing equilibrium (2) it could be concluded that the main component with decreasing of which it is possible to decrease the technological cost is:

Cm – expenses on used and procured materials, decreasing of which *ceteris paribus* could be achieved by reducing of wastage at fabrication of composite airframes by innovative technological techniques. It is noteworthy to mention that wastage in some cases is about 50% and more.

Cw – reducing of expenses on salaries and wages workers within the production could be achieved by means mechanization and automotization of technological processes of production of airplanes and by using the special technological equipment, which always proves and refunds itself in the case of serial production of units. Consequently, decreasing of Cw directly is linked to relation Cse/N in the equilibrium (2). Increasing of volume of production N till several thousand units leads the necessity to create the special technological equipment for serial production of airframes of flying apparatus. In such cases the issue of designing of integral airframes with minimal disjunctions becomes the drastic factor of providing the minimal technological cost of unit. In such cases unifying of structuring technological and operational disjunctions could become the main mean of reducing of quantity of technological equipment for serial manufacturing of airframes till several units, which ultimately will serve for decreasing of technological cost of serial N.

TYPICAL TECHNOLOGICAL PROCESS

Typical technological process fabrication of integral monolithic airframes includes the following operations and transitions:

1. Lay up of fabric on lower negative semi press form;
2. Set up of metal framework into lower negative semi press form and its positioning upon basis point;
3. Set up of pneumatic bag into metal framework;
4. Lay up of fabric on the metal framework and pneumatic bag;
5. Set up of upper negative semi press form on the lower;
6. Pneumatic bag inflation and fabric on the press form wall application;
7. Curing processes.

It includes the following works and operations:

- Making master-model of airfoil shell.
- Making the negative semi-forms airfoil shell on master-model.
- Lay up of glass-fiber shell on the outwardly negative semi press form.
- Curing in the outwardly negative press form glass-fiber cloth shell using bag-molding technology.
- Preparing outwardly negative semi press form for setting in the metal framework and positioning the framework with found upon basis point.
- Join outwardly airfoil shell with metal framework.
- Making internal shell in positive press form with glass-fiber cloth laid up with epoxy resin.
- Setting up of the finished inwardly shell into negative press from on the joined airfoil shell and metal framework on the basis point with glue and mechanical fixation.
- Forming of the constructive, technological and operating disjoin.
- Preparing lower and upper negative semi-form of airfoil shell for conjunction.
- Setting up of pneumatic bag in internal cavity of airfoil shell.
- Connection of lower and upper semi-forms of airfoil shell.
- Completion of gluing process.
- Opening of negative semi-forms and withdrawal monolithic whole-compositional airfoil shell.
- Receiving with positive press-forms wing and fuselage fuel tanks shells.

- Completion and join the finished wing and fuel tanks shell with semi wing and fuselage.
- Fill the space between and outwardly shells with light inert filler, for example with foam plastic.
- Out the excess, reduce work and inspection.
- Painting of finished whole-compositional airfoil shell.
- Final inspection

IMPACT TO DESIGN PRINCIPLES

The main direction of creation of LLCC from designing point of view is development of airframes with maximum volume efficiency. This stipulates the maximal meaning of correlation of volume V of the airframe to the surface S of the same airframe. Because of the weight of compositional airframe by the major part is function direct proportional SxΔ, where Δ is the average 'weight thickness' of the airframe. Increasing of volume efficiency stipulates increasing of weighting efficiency, and from this point of view it could be considered the new principle pre-feasibility study when the initial main parameter is volume but not weight of useful loading. Determining the configuration of useful volume under sizes of useful loading and knowing its total mass we could start determining the main designing parameters of flying apparatus. For relatively small and light apparatus with weight 500-1000 kg it would be necessary to use the approach described above. We could assume that this kind of apparatus will be enlargement of lifting body with the small control surfaces included in adapting system of control. As a rule, lifting bodies present itself integral bodies, which are suitable for the mentioned fabrication principle of latter in to disjunction press forms using pneumatic bag method.

In the given approach the metallic framework in the structure of the airframe is carrier of both main-loading function leaving for composites secondary and in some meaning also primarily function, but is carrier also technological function, which means that in the process of the manufacturing of the airframe serves as framework, mach, cell on which is laying liner for further curing process. The approach to designing of metal frameworks giving possibility to realize the following principles: all or almost all elements should perform load function as well as free-edge-disjoin function for structural and operational disjoining and moving elements, for instance the loading should mainly on metallic elements of frames of doors and hatches. Their structure should involve the following functions: loading, envisaging transmission of main loading; technological, envisaging two technological functions: 1) joining-technological function, envisaging forming of

free edge of composite-metal coupling and; 2) assembling-technological, envisaging function of frame (bench) holding of layer until inflation of pneumatic bag and compressing to the wall of press form before polymerization and structural and operational targeting main function. Multi functionality of structural elements of structure of loading framework enables significantly reducing weight and manufacturing cost.

One of the important questions to be solved in order to develop manufacturing technology of integral airframes is the study the behavior of Metal-Composite Coupling (MCC) into functional elements of airframes. Such MCC is common on structural and operational disjoints such as doors, hatch's etc., and in case of constructing metal-join-composite-structure combination which are necessary for provision of moving connections of units, such as main and bow legs, rudders etc., and to fixation of immovable units, such as engines, equipment's etc.

As a rule, such of MCC represents heavy loaded structural elements of airframes and perhaps its fatigue strength defines general recourses of airframes. That is why a careful study and development of high reliable MCC is an important search problem to create the perfect integral airframes.

The different properties of the metals and composites, particularly homogeneity and isotropy, impact viscosity, electrical conductivity, corrosiveness and especially coefficient of thermal expansion, dictate a special design approach and proper fabrication techniques of metal-composite coupling. In this point of view more importantly seems choice of cohesion surface features of them.

There must be distinguished two variants of choice of MCC design. First, when into composite was inserted relatively small metallic particles and second, when we have a complex metallic framework into composite is incorporated. In first case, we need only to gave to metallic contact surfaces much more cohesive properties because absolute thermal dimension change in this case is negligibly small. But in second cases especially when we acted with a large 3D complex structures the feature of Metal-Composite Coupling design must be chosen by foreseen of the fact that absolute thermal dimension (both working and technological) change may be sufficient for origin large internal tenses in MCC. Therefore, an appropriate computer modeling and trial methods should be experienced and developed in order to be assured that chosen design features of MCC are valid and fatigue resistance of MCC have a necessary level attained.

TECHNOLOGY AFFORDABILITY

What kind of 50 years composite materials experience and technological achievement should be serve for implementation of Low Cost manufacturing technology proposed? From material aspect there are a significant achievements in the increasing of carbon fiber thickness with acceptable mechanical properties (i.e. tensile modulus, tensile strength, elongation, etc.), weight and purchasing costs. Introduction of resin film made possible to exploit Resin Film Infusion (RFI) process for large structural parts manufacturing technology. Non Crimp Fabric (NCF) layers gives opportunity to lay up of part with hard surface complexity.

The manufacturing effort to develop an inovative semipreg technology which consists in recovering a thick dry fiber tape with a thick resin film made possible to manipulate only one intermediate resin - fiber product. Although this new technology needs some work to be technicaly validated, such achievement is hardly overestimated. Another modern specific materials, such as antiadhesires, laminates, surface mats etc. also serve to solve the important problems of monolithic composite airframes manufacturing.

Therefore, we could say that there are no more dimension limitations in monolithic airframe processing and further composite material development should be focused on upgrading of its characteristic.

As for process aspect, there are no doubts, that use of special self heating large press forms- moulds for monolithic composite airframes fabrication instead of large mould - large autoclave techniques is the factor of cost reducing. Application of disconnection negative press-form cut off which corresponds to the perimeter of the apparatus in the plan coupling with pneumatic bag installation inside and special care techniques to eliminate all of the air from mould after hand lay up and closing of press-form make possible to handle polymerization (cure) process with convenient tolerance band in parameters and serve to improve the level of reliability delivering of ready airframes without of off-size, off-grade and without of wastage. Creation of predictable and reproductionable technology is main advantages of proposed processes.

Materials, equipments, techniques and technology, counted above coupled with another know-how, gives possibility to create a truly perfect low life cycle cost carbon fiber-epoxy resin composite airframes as sandwich type monolithic integral shell with built in metal framework.

SUMMARY

The development and creation perfect Low Life Cycle Cost composite airframes closely linked with application of monolithic integral shell fabrication techniques and processes. Design step Integration of structural parts to whole monolithic airframes and development of suitable equipment for its manufacturing is one of the main directions of decreasing manufacturing cost. The proposed design and technological approach is equally applicable both to civil and military aircraft airframes production. Principles offered give possibility to designers and manufacturers to use it as further tool in developing a truly Low Life Cycle Cost composite monolithic airframes, that may not have been feasible otherwise with common methods.

Flight Problem Research and Development Society of Georgia hopes to break 10 years isolation and extend the technology and collaborative base with worldwide scientific community for close integration in appropriate works.

BIBLIOGRAPHY

1. Vigdorchik C.A.-Technological basic of design and drawing of aircraft. Moscow, MAI, 1974
2. Gorbunov M.H.-Basic of fabrication technology of aircraft, Moscow, Mashinostroenie, 1976
3. Avduevski V.C,Ishlinski A.I.,Obrazcov U. F.-Scientifical basic of advanced techniques and technologies. Moscow, Mashinostroenie 1985.
4. Gimmellfarb A.L- Basic of design in aircraftbuilding. Moscow, Mashinostroenie, 1980
5. Pkhaladze N.W.-Research of the technological process and development the technological equipment for making whole compositional airfoil shell of light flying apparatus with built in metal framework. NATO RTO AVT panel spring symposium and specialists meeting. Braunshweig, Germany, 2000
6. Pkhaladze N.W.-Biplane. Invention #3007 GE. The Georgian National Center of the Intellectual Property "Sakpatenti" 2000.
7. Bauer I. -Increasing productivity in composite manufacturing. NATO RTO AVT Panel spring symposium and specialists' meeting Loen, NORWAY, 2001.
8. Wood G., Petrescue L., Jonston A. - Design and certification of a Vacuum –Assisted Resin Transfer Moulded Composite Seaplane Float. NATO RTO AVT Panel spring symposium and specialists' meeting Loen, NORWAY, 2001.

9. Deo R.B.,Starnes I.H.J.R., Holzwart R. C., Low -Cost Composite materials and Structures for Aircraft application. NATO RTO AVT Panel spring symposium and specialists' meeting Loen, NORWAY, 2001.
10. Cinquin I. -Aeronautical composite Structure cost Reduction from the material Aspect. NATO RTO AVT Panel spring symposium and specialists' meeting Loen, NORWAY, 2001.
11. Starnes I. H. Ir., Dexter H. B., Jonston N. I., Ambur D. R., Cano R. I. -Composite Structures and materials research at NASA LANGLEY Research center, NATO RTO AVT Panel spring symposium and specialists' meeting Loen, NORWAY, 2001.
12. Mills A., Backhouse R. -Innovative materials and manufacturing processes for the cost effective manufacturing of composite airframe structures. 44th International SAMPE symposium and exhibition, Long Beach, CA, USA, 23-27 May 1999. P 2255-2267.

This page has been deliberately left blank

Page intentionnellement blanche

The NATO Research & Technology Organization (RTO) – Overview

Claude Mounier, RTA/SPD
7, rue Ancelle
92200 Neuilly-sur-Seine
France

In the interests of readability and understandability, it is RTO policy to publish PowerPoint presentations only when accompanied by supporting text. There are instances however, when the provision of such supporting text is not possible hence at the time of publishing, no accompanying text was available for the following PowerPoint presentation.

Click here to view PowerPoint presentation; Press Esc to exit

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

This page has been deliberately left blank

Page intentionnellement blanche

Strategic Cost Model to Support High Level Operational Analysis

Duncan Barradale
Technical Leader Cost Analysis
A2 Building
Farnborough, Hampshire
GU14 0LX
United Kingdom

In the interests of readability and understandability, it is RTO policy to publish PowerPoint presentations only when accompanied by supporting text. There are instances however, when the provision of such supporting text is not possible hence at the time of publishing, no accompanying text was available for the following PowerPoint presentation.

Click here to view PowerPoint presentation; Press Esc to exit

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

This page has been deliberately left blank

Page intentionnellement blanche

Realistic Cost Estimates for Acquisition Programs: CAIG Perspectives

Richard Burke
Office of Secretary of Defense
Program Analysis and Evaluation
1800 Defense Pentagon, Room BE829
Washington, DC 20301-1800, USA

Introduction

My remarks today will focus on 3 specific questions:

1. Why do we do realistic cost estimates?
2. How we develop and use the cost estimates?
3. How successful are we?

In addressing these questions I hope to provide the CAIG perspective on the need for realistic cost estimates in the acquisition of major military systems. I will conclude my remarks with a discussion of the road ahead for the CAIG in developing realistic cost estimates for US programs.

Why Do We Do Realistic Cost Estimates?

The answer to this question is obvious to those in the US involved with the formulation of the defense acquisition budget. It is not well known to all in the acquisition world, however. Hence, it may be useful to begin by stating why we work so hard at getting realistic estimates of the costs of major acquisition programs.

The question really is why we are so concerned with *life cycle costs*—that is, development, procurement, and operations and support costs year-by-year for a period which at the start of engineering and manufacturing development (i.e., equivalent to the design and development phase in NATO acquisition) can extend for 30 years and more. Program managers are strongly motivated to make realistic forecasts of their costs a year or two in advance to justify their near-term budgets. But why such concern with costs over horizons of 10, 20, or 30 years in the future?

Without wishing to insist to firmly on the relevance of estimates of costs that will occur far in the future, the answer to this question is to be found in a combination of three considerations. First, in the acquisition world, decisions made “today” strongly influence funding requirements not just for “this year” but also for “next year” and many years thereafter. To take an obvious example, the decisions that will be made on the Joint Strike Fighter program are likely to be a major factor in partners’ tactical aircraft procurement programs for decades. Second, programs typically are relatively “cheap” in their initial stages, especially the early stages of development, but require much larger annual funding later, during the procurement phase. Third, the overall budget of the US Defense Department is subject to constraints; spending on particular parts of the budget (e.g., Army aircraft procurement) are also constrained, although somewhat less specifically.

Paper presented at the RTO SAS Symposium on “Cost Structure and Life Cycle Cost (LCC) for Military Systems”, held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

It goes without saying that demand for investment funds exceeds the amounts available. It is generally perceived that, in the competition for funds, Fortune tends to favor systems that promise outstanding performance at an affordable cost. Hence, program advocates have reason to take an optimistic view of both performance and cost. To the extent that optimistic appraisals of cost are adopted, the acquisition budget as a whole will be "over programmed;" that is, the Department will begin the development of more programs than can be completed at efficient procurement rates.

The question of why we need realistic cost estimates then becomes: What is wrong with "over programming" the acquisition accounts. The answer is that over programming, to the degree that it actually occurs, is wasteful in that it causes the total cost of the procurement program to be greater than it needs to be.

The mechanisms through which over programming increases the costs of obtaining a given capability within a given time frame are straightforward. Over programming becomes a fact that must be recognized when budgets for the next year or two are put together. At that point, contracts are pending or in place, and, in contrast to the outyears, program managers are strongly motivated to adopt realistic cost estimates. The need to adjust the acquisition program in response to a shortage of funds (due to over programming) of course can be avoided to the degree that there is some source of additional funding outside the acquisition program. This is not something that can be counted on; at least to a considerable extent, the services and other DoD components have found that they must deal with the problem within pre-existing funding limits.

At least in the US, substantially reducing the capabilities or performance of the military system to be acquired has not usually been a serious option. Occasionally the response has been to cancel one or more programs, which is wasteful to the extent that the development efforts of the canceled programs have no utility to programs that are eventually funded. More common, the funding shortages caused by over programming are accommodated by stretching ongoing programs—that is, by lengthening the time over which the development is accomplished and/or reducing the quantity of the system procured each year. This increases costs if only because fixed costs must be carried for more years, and usually for other reasons as well.

At roots, then, we seek realistic costs for individual major acquisition programs because a clear eyed view of cost is needed to economically structure the acquisition program as a whole. Good stewardship of the resources allocated to the Department is something that the senior leadership of DoD requires. It is also something that the Congress insists upon and is, therefore, something that DoD must do reasonably well if it is to remain master over its own programs.

How do We Develop and Use Cost Estimates

The process for estimating costs for major defense acquisition programs in the DoD is relatively well established. The process involves the preparation of two separate life cycle cost estimates for each major decision point in the lifetime of an acquisition program. The two cost estimates are presented to the Defense Acquisition Board, the oversight and advisory body in the DoD for major military acquisition programs, at each major milestone review.

The US manages the acquisition of major military systems through a milestone decision process. In broad terms, the process presumes that a well managed acquisition program proceeds through several distinct phases. The point of transition between phases, where work on one has been completed and work on the next not yet begun, is termed a "milestone." (The number of milestones has varied from three to six over the roughly 30 years that DoD has used a milestone acquisition process.) The overarching question at each milestone is whether the system is ready

in all respects to go on to the next phase. The authority to make that decision for a major weapon system acquisition rests with the Secretary of Defense. From the start of development through the early stages of production, the authority to make the decision is ordinarily delegated to the Under Secretary of Defense (Acquisition, Technology and Logistics) USD(AT&L). Then, absent positive approval by USD(AT&L), the service conducting the acquisition cannot spend funds on activities associated with the next phase (e.g., could not spend funds on characteristically design and development activities for a system at the end of the program definition and risk reduction phase.)

Milestone approval covers a substantial list of topics—among others, the technical goals the system is to achieve, test and evaluation plans, a contracting plan (e.g., multi-year vs. single year procurement), procurement quantities, and—of particular interest here-- cost and budget. Decisions by USD(AT&L) on budget for an acquisition program are not final, as they are subject to change in the DoD resource allocation process, by the Office of Management and Budget, and ultimately by the Congress. Those initial decisions on cost and budget are very influential, however.

There are two life cycle cost estimates prepared for each milestone review of a major defense acquisition program in the US. One estimate is prepared by the military service responsible for managing the acquisition of the system under consideration. In some instances this cost estimate is prepared within the program office itself, under the direct management of the program manager. For other programs, this cost estimate may be prepared in a centralized organization within the military department responsible for the acquisition program. The cost estimate prepared by the military department is coordinated throughout the military service and presented to the USD(AT&L) as part of the DAB review process.

Another separate life cycle cost estimate is prepared for the military system at each major milestone in the US acquisition process. By statute, at decisions on entry into Engineering and Manufacturing Development (i.e., EMD, known as the "Design and Development" phase in the NATO acquisition community) and into Full Production the USD(AT&L) must also consider an independent cost estimate, that is, an estimate made by an organization that does not report to the chain of command of the sponsoring military service. The responsibility for making the independent cost estimates is assigned by DoD regulations to the Cost Analysis Improvement Group (CAIG), which effectively is a large part of the Resource Analysis deputate of the Office of Program Analysis and Evaluation. The CAIG has available to it substantially the same historical data and cost information as the military service, but makes its own judgments about assumptions and costing methods.

Why is there a need for two separate life cycle cost estimates at each milestone for acquisition of major military systems? There are several important reasons the DoD acquisition process has for three decades included the preparation and consideration of two cost estimates at each key decision point.

As discussed earlier, there is a natural tendency to adopt optimistic cost estimates resulting in over programming of the acquisition accounts relative to the fiscal constraints facing the DoD and the military services. The consideration of the second independent cost estimate at each major milestone serves as a direct counterbalance to the natural tendency to adopt overly optimistic cost estimates. It is quite frequently the case that the CAIG independent cost estimate is higher than the service cost estimate because of less optimistic assumptions used in developing the CAIG estimate of costs.

The consideration of two cost estimates also results in a form of competition between the military service preparing the service cost estimate and the CAIG analysts preparing the independent cost estimate for major milestone reviews. There are several reasons this informal

competition is healthy from a DoD corporate perspective. First and foremost, competition improves the quality of cost estimates available for use in the Department for managing acquisition programs and budgets. The benefits of good, reliable cost estimates accrue to the Department over time in the form of enhanced credibility in dealings with the executive branch of government, the White House, the Congress, and perhaps most importantly, directly with the American people.

A second major benefit of the informal competition in preparation life-cycle cost estimates is that it provides an incentive for the military services and the CAIG to maintain and improve the cost analysis methods, information sources, and human resources needed to produce the life-cycle estimates. Over time the consideration of two cost estimates has resulted in better definition of cost analysis procedures and processes, improved analytic techniques and information resources, and improved training of the human resources devoted to the costing of major military systems in the DoD.

A third benefit of having two cost estimates available for consideration at each milestone review is that the cost estimates themselves serve as vehicles for identifying major program risk areas for consideration by the acquisition executive. At each milestone review the military services and the CAIG compare the cost estimates side-by-side, explaining the substantive differences between the two cost estimates. Most often, the differences in estimates can be traced directly to two or three key assumptions used in developing the cost estimates. It is precisely these assumptions that identify key risk areas in the program under review. For example, the CAIG cost estimate may differ substantially from the service cost estimate because the proposed program schedule is overly optimistic based on DoD experience with prior programs in a specific commodity class. In this situation, the comparison of cost estimates may lead the acquisition executive to establish a more realistic schedule for the program prior to milestone approval and entry into, for example, the EMD phase.

There are serious differences between the service and the CAIG cost estimates in perhaps 30 percent of the cases that are reviewed by USD(AT&L). In these, the decision on the cost estimate to be used, and therefore on the resources budgeted for the system, is made by USD(AT&L).

The cost estimates prepared in support of USD(AT&L) establish a basis for decisions on the budget of the system under review. The presumption is that budget equals cost. This does not mean the budget for the upcoming year or two, but the year by year budget through the planned conclusion of the procurement.

Cost and budget issues, although they can arise at any stage, tend to be most crucial at the point at which the decision to enter EMD (i.e., the equivalent of the D&D phase in the NATO acquisition process) is made. Typically, the annual expenditure rate increases sharply at the start of EMD, and the program attracts so many adherents that it becomes very difficult to cancel. Moreover, the forecasting challenges, and hence the possibility of legitimate controversy, tend to be greatest around the start of the EMD (or D&D) phase.

Measures of Success

It is fruitful take a step back and examine the degree to which we have achieved success in developing and using independent cost estimates for DoD programs. In the CAIG we maintain an ongoing process to evaluate our success in estimating costs. We do this by comparing our independent cost estimates for programs prepared at the start of the EMD and production phases of programs, with the actual costs of the program measured at the completion of each of these program phases.

It is helpful to review the significant long-term problem that that led to the formation of the Cost Analysis Improvement Group (or CAIG) in 1971. At that time, the Deputy Secretary of Defense, David Packard, was plagued with sharp criticism because of continuing problems with major acquisition programs that were encountering very severe cost growth—growth of approximately 100-400% above contractor cost estimates were typical during this period. Chart 1 shows the approximate situation posed to Deputy Secretary of Defense Packard in 1971. Of the 34 major systems shown on the chart, 15 had projected cost overruns greater than 100%. These large overruns were, as you can imagine, causing numerous headaches for the Deputy Secretary—problems with insufficient budgets for execution of programs, extensive schedule delays and program changes, and, perhaps most importantly, problems with the US Congress.

Mr. Packard traced the source of the problem with large cost overrruns on military system acquisition programs to the poor quality of cost estimates prepared by military contractors and the military departments. His response was to direct the development of an independent cost estimating process to improve the quality of cost estimates for major defense acquisition programs. In early 1972 the Secretary of Defense affirmed the recommendations of Deputy Secretary Packard and established the OSD Cost Analysis Improvement Group.

As we step back, now thirty years later, and measure the success of independent costing, we no longer find ourselves in a situation where cost growth of 100-400% is typical for major military acquisition programs in the U.S. The historical information on actual program costs shows that independent cost estimating has dramatically reduced both the occurrence and the size of cost overruns for major defense acquisition programs. Recent experience since the early 1980s shows that growth of acquisition costs for major programs averaged approximately 30-50%, well below the levels routinely experienced by David Packard as the Deputy Secretary of Defense. In fact, the record since the 1980s shows that the problem with large, unanticipated cost growth on major weapon systems has been largely solved.

Chart 2 shows acquisition cost growth for small systems, large systems, and large and small systems considered in aggregate. The chart presents a histogram of the number of systems experiencing cost growth at levels less than 0%, 0-20%, 20-50%, and greater than 50% relative to the original cost estimate for the acquisition program prepared at the start of the EMD phase. The red bars show DoD experience with programs prior to 1983. The blue bars show experience during 1983-1996, a time period in which the reforms introduced by Deputy Secretary Packard were in full effect. As shown on Chart 2, only one in ten DoD systems had cost growth greater than 50% during 1983-1996, a marked improvement from the situation facing the Deputy Secretary of Defense a decade earlier.

Where Do We Go From Here

I'd like to close my remarks with a look ahead at the path we plan to pursue to ensure the DoD continues to improve processes, analytic tools, and the human resources necessary to develop realistic cost estimates for the acquisition of military systems.

First, we continue to pursue improvements in the tools and processes used in DoD to estimate the costs of major military systems. The CAIG, as well as the military services, continue to expend significant financial and human resources in pursuit of improvements in our cost analysis methods, information sources and databases, and procedures for developing cost estimates. For example, later this afternoon you will hear from Colonel Dave Robinson, the Director of the Contractor Cost Data Reporting (CCDR) office in DoD. He will provide a discussion of improvements that have been implemented in the CCDR system, and plans for future improvements to information sources and data systems available to cost analysts. The

CCDR system will continue to provide an efficient means to collect cost actuals from ongoing acquisition programs to support analysts in preparing cost estimates new programs. We continue to pursue improvements as needed in the Cost Analysis Requirements Document, Work Breakdown Structures, VAMOSC, and other tools used for cost analysis —many of which will be discussed during this two-day conference. Lastly, we are working to improve the number of training opportunities and the quality of training available for human resources in the costing community. Early next year we will once again support the 35th Annual DoD Cost Analysis Symposium to meet our training objectives.

Second, we are pursuing the application of cost estimating and analysis methods to address DoD financial management problems beyond the scope of the acquisition of major military systems. For example, it is obvious to us in the US that the Department will be facing new challenges in acquisition of large service contracts, and in the acquisition of health care services from private contractors to provide services to active duty personnel, dependents, and retirees.

Finally, we continue to extend the practice of developing realistic cost estimating to other government agencies and international organizations. The number of government agencies and international organizations requesting assistance or expressing interest in developing realistic life cycle cost estimates continues to grow. In some cases, agencies are seeking guidance on how to establish new independent costing organizations to develop realistic cost estimates in support their acquisition programs. We shall support these activities to the degree possible because we continue to believe that realistic costing is a central element of sound financial management of major government acquisition programs.

Overview of the Symposium Topics

Gérard Seguin
DGA/DPM/MCO/EL
26, Boulevard Victor
00460 Armées
France

In the interests of readability and understandability, it is RTO policy to publish PowerPoint presentations only when accompanied by supporting text. There are instances however, when the provision of such supporting text is not possible hence at the time of publishing, no accompanying text was available for the following PowerPoint presentation.

Click here to view PowerPoint presentation; Press Esc to exit

Paper presented at the RTO SAS Symposium on "Cost Structure and Life Cycle Cost (LCC) for Military Systems", held in Paris, France, 24-25 October 2001, and published in RTO-MP-096.

This page has been deliberately left blank

Page intentionnellement blanche

Discours de clôture

I.G.A. Bernard Besson
DGA–IPE
8 boulevard Victor
F-00303 Armées
France

Bonjour, bon après midi plutôt…

D'abord, je vous promets d'être bref parce que je sais que certains d'entre vous ont des avions ou des trains à prendre ce soir et que ceux qui ne partent pas, veulent peut-être profiter du soleil à Paris. En cette période ce n'est pas tous les jours.

Pourquoi m'adressai-je à vous maintenant ? C'est parce que d'abord je suis au sein de la Délégation Générale pour l'Armement, à la tête d'une équipe, dite les Architectes de Systèmes de Forces (ASF), qui est chargée de préparer les choix sur les capacités futures des armées françaises. Et, comme vous l'a dit l'ingénieur général Bongrand, en ouverture hier matin, la vision globale du coût est évidemment un élément majeur dans la gestion des dossiers de préparation des choix importants pour les forces. Alors, au cours de ces deux jours vous avez échangé un certain nombre d'études, de données, et j'ai noté, j'ai relevé quelques problèmes. Je n'ai pas assisté à l'ensemble de vos travaux, mais il y a quelques problèmes qui, me semble-t-il, ont été mis en évidence, qui démontrent qu'il y a encore du travail pour les responsables d'établissement des coûts, c'est d'abord s'attacher à la qualité des bases de données dont j'ai bien noté qu'elle était essentielle, à la validité des modèles qui étaient employés. Et, même quand les données de bases sont les mêmes, la base de données peut introduire son facteur personnel. J'ai bien noté que, par exemple aux Etat-Unis, quand on fait des évaluations indépendantes on arrive à 30 % d'écart à partir de données des bases dont on pourrait penser qu'elles sont les mêmes. C'est donc vraiment un problème de fond, cette qualité, ce souci de vision de l'information, qui est nécessaire au travail.

Deuxième facteur qui me paraît important, c'est l'organisation des acteurs dont certains ont dit qu'ils étaient indépendants et qui déterminent, par leur organisation, la structure des coûts. C'est un secret pour personne que, quand on compare déjà des armées entre elles, par exemple la marine et l'armée de terre, l'organisation étant différente, la structure des coûts de soutien, de fonctionnement ne va pas être la même. Et pour nous, qui préparons des choix sur des équipements futurs, des capacités futures, dont la majorité sera sans doute réalisée en coopération internationale, ces problèmes de différence d'organisation sont encore plus importants, quand on se met à plusieurs pays. Or il est clair que, pour se comprendre et pour voir l'influence du choix sur les structures de coût, il faut avoir un langage commun qui permet d'expliquer le poids des organisations.

Communication présentée lors du symposium RTO SAS sur les « Structures de coûts et coûts globaux de possession (LCC) pour systèmes militaires », organisé à Paris, France, du 24 au 25 octobre 2001, et éditée dans RTO-MP-096.

Enfin il y a un troisième problème, que personnellement je n'ai encore pas vu bien abordé même si la méthode britannique de comptabilité économique de type entreprise s'en approche, c'est la comparaison, pour un choix, de systèmes dont la durée de vie est différente. Quand on doit prendre une décision sur un renouvellement d'équipement ou sur une modernisation d'équipement, on a généralement le choix entre un achat sur étagère, "SCOTS" en anglais, ou développer un système nouveau, ou faire une modernisation importante d'un système existant. Il est clair que les durées de vie de chacun de ces choix ne sont pas les mêmes, et comment, par une approche de coût global, peut-on rendre compte de l'équilibre des choix alors qu'on ne va pas donner le même potentiel ? Il y a un problème de modélisation important, qui, à mon sens, n'est pas encore résolu. Donc vous avez encore du travail.

Voilà les trois points que je voulais noter. Je tire aussi de ces journées le fait que déjà, d'avoir pu parlé ensemble, de mettre ensemble toutes ses expériences, est la première démarche pour que, dans notre monde de la défense au moins, on puisse se comprendre et savoir de quoi on parle tous ensemble. C'est un facteur de progrès.

Alors maintenant j'ai une deuxième raison de m'adresser à vous ce soir, c'est que je suis le représentant national pour la France au Panel SAS qui sponsorise, si j'ose dire, ce symposium. Alors d'abord, au nom du Panel, je dois dire que je me félicite que ce symposium se soit tenu parce que c'est un témoignage vivant de la qualité des activités que nous essayons de promouvoir. Je remercie donc tous ceux qui ont pris la peine de venir ici pour témoigner, présenter des conférences et mettre leur savoir en commun.

Cette étude sur les modèles de coûts est née il y a deux ans du résultat d'une étude sur le véhicule tout électrique (VTE) où les pays de l'Alliance essayaient de comparer leur approche de cette problématique, et s'étaient aperçu que, pour évaluer les différents systèmes, il fallait parler de coûts, et que, malheureusement personne n'avait un modèle de coût qui soit satisfaisant et qui permettait d'en rendre compte. Donc l'idée a été émise qu'on pourrait lancer une étude sur les modèles de coûts qui s'est transformée d'ailleurs dans son intitulé sur la structure de coûts et non sur les modèles de coûts. Compte tenu des échanges auxquels j'ai assisté, je pense qu'il y a de quoi lancer encore des études pour la suite, pour améliorer, maintenant qu'on a posé peut-être quelques bases de langage commun, un travail, pour arriver effectivement à des modules de coûts sur lesquels nous serons d'accord, que nous saurons les gérer ensemble et ce qui permettra effectivement d'approcher une vision partagée entre tous les membres de l'Alliance et les pays partenaires des questions de coûts.

Donc j'invite chacun d'entre vous, rentré à la maison, rentré dans son pays, à discuter avec ses autorités, ses représentants vis à vis du Panel pour savoir, après une réflexion, après la digestion de tout ce qui a été dit aujourd'hui, quelle suite vous souhaiteriez voir donner, c'est vraiment une question que le Panel doit se poser prochainement.

Enfin, en tant que représentant du Panel, il m'appartient de faire quelques remerciements pour la tenue de ce symposium. D'abord je remercie le service communication (COMM) de la DGA qui a veillé à l'organisation matérielle du symposium. Je pense qu'à voir votre attitude vous en êtes à peu près satisfaits, donc je remercie en votre nom et au nom du Panel. Je remercie aussi l'équipe de

l'agence, de la RTA et Mme Louise Choquette qui a apporté un soutien dans la préparation de ce symposium et dans la gestion des participants. Je remercie les interprètes pour leur travail qui, j'espère, a été apprécié, même si de temps en temps on ne trouvait pas le bon canal ou le micro ne marchait pas. Et enfin je remercie le comité d'organisation du symposium et particulièrement le directeur d'études Gérard Seguin pour la réussite de ces deux jours.

Merci beaucoup !

Page intentionnellement blanche

This page has been deliberately left blank

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's References	3. Further Reference	4. Security Classification of Document
	RTO-MP-096 AC/323(SAS-036)TP/27	ISBN 92-837-0034-1	UNCLASSIFIED/ UNLIMITED

5. Originator Research and Technology Organisation
North Atlantic Treaty Organisation
BP 25, F-92201 Neuilly-sur-Seine Cedex, France

6. Title

Cost Structure and Life Cycle Cost (LCC) for Military Systems

7. Presented at/sponsored by

the RTO Studies, Analysis and Simulation Panel (SAS) Symposium held in Paris, France, 24-25 October 2001.

8. Author(s)/Editor(s)	9. Date
Multiple	June 2003

10. Author's/Editor's Address	11. Pages
Multiple	196 (text) 508 (slides)

12. Distribution Statement There are no restrictions on the distribution of this document. Information about the availability of this and other RTO unclassified publications is given on the back cover.

13. Keywords/Descriptors

Armed forces procurement
COO (Cost of Ownership)
Cost analysis
Cost control
Cost effectiveness
Cost engineering
Cost information management
Economic analysis
LCC (Life Cycle Cost)
Life cycle costs
Life cycles
Logistics
Maintenance
Maintenance management
Military planning
Service life
TOC (Total Ownership Cost)
Value engineering
WLC (Whole Life Cost)

14. Abstract

Cost, not limited to acquisition costs but all costs involved in the use and disposal of systems, has become a major issue in military systems analysis. In order to harmonize the most important aspects of Life Cycle Cost (LCC) a study was carried out by Technical Team SAS-028 covering three concurrent aspects: the cost breakdown structure that defines and organises all cost elements to be considered, the boundaries of those cost elements defined by LCC, TOC, COO and WLC and the uses of those concepts (economic or financial analysis, optimisation, etc.) by decision makers.

Following this study, a symposium entitled "Cost Structure and Life Cycle Cost (LCC) for Military Systems" was held in Paris from 24 to 25 October 2001. Twenty-two papers, focusing on concepts such as Life Cycle Cost (LCC), Whole Life Cost (WLC), Cost of Ownership (COO) or Total Ownership Cost (TOC), were presented.

This page has been deliberately left blank

Page intentionnellement blanche

NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION
BP 25 • 7 RUE ANCELLE
F-92201 NEUILLY-SUR-SEINE CEDEX • FRANCE
Télécopie 0(1)55.61.22.99 • E-mail mailbox@rta.nato.int

DIFFUSION DES PUBLICATIONS
RTO NON CLASSIFIEES

L'Organisation pour la recherche et la technologie de l'OTAN (RTO), détient un stock limité de certaines de ses publications récentes, ainsi que de celles de l'ancien AGARD (Groupe consultatif pour la recherche et les réalisations aérospatiales de l'OTAN). Celles-ci pourront éventuellement être obtenues sous forme de copie papier. Pour de plus amples renseignements concernant l'achat de ces ouvrages, adressez-vous par lettre ou par télécopie à l'adresse indiquée ci-dessus. Veuillez ne pas téléphoner.

Des exemplaires supplémentaires peuvent parfois être obtenus auprès des centres nationaux de distribution indiqués ci-dessous. Si vous souhaitez recevoir toutes les publications de la RTO, ou simplement celles qui concernent certains Panels, vous pouvez demander d'être inclus sur la liste d'envoi de l'un de ces centres.

Les publications de la RTO et de l'AGARD sont en vente auprès des agences de vente indiquées ci-dessous, sous forme de photocopie ou de microfiche. Certains originaux peuvent également être obtenus auprès de CASI.

CENTRES DE DIFFUSION NATIONAUX

ALLEMAGNE
Streitkräfteamt / Abteilung III
Fachinformationszentrum der Bundeswehr, (FIZBw)
Friedrich-Ebert-Allee 34
D-53113 Bonn

BELGIQUE
Etat-Major de la Défense
Département d'Etat-Major Stratégie
ACOS-STRAT-STE – Coord. RTO
Quartier Reine Elisabeth
Rue d'Evère, B-1140 Bruxelles

CANADA
DSIGRD2
Bibliothécaire des ressources du savoir
R et D pour la défense Canada
Ministère de la Défense nationale
305, rue Rideau, 9e étage
Ottawa, Ontario K1A 0K2

DANEMARK
Danish Defence Research Establishment
Ryvangs Allé 1, P.O. Box 2715
DK-2100 Copenhagen Ø

ESPAGNE
INTA (RTO/AGARD Publications)
Carretera de Torrejón a Ajalvir, Pk.4
28850 Torrejón de Ardoz - Madrid

ETATS-UNIS
NASA Center for AeroSpace Information (CASI)
Parkway Center
7121 Standard Drive
Hanover, MD 21076-1320

FRANCE
O.N.E.R.A. (ISP)
29, Avenue de la Division Leclerc
BP 72, 92322 Châtillon Cedex

GRECE (Correspondant)
Defence Industry & Research General Directorate
Research Directorate
Fakinos Base Camp
S.T.G. 1020
Holargos, Athens

HONGRIE
Department for Scientific Analysis
Institute of Military Technology
Ministry of Defence
H-1525 Budapest P O Box 26

ISLANDE
Director of Aviation
c/o Flugrad
Reykjavik

ITALIE
Centro di Documentazione Tecnico-Scientifica della Difesa
Via XX Settembre 123a
00187 Roma

LUXEMBOURG
Voir Belgique

NORVEGE
Norwegian Defence Research Establishment
Attn: Biblioteket
P.O. Box 25, NO-2007 Kjeller

PAYS-BAS
Royal Netherlands Military Academy Library
P.O. Box 90.002
4800 PA Breda

POLOGNE
Armament Policy Department
218 Niepodleglosci Av.
00-911 Warsaw

PORTUGAL
Estado Maior da Força Aérea
SDFA - Centro de Documentação
Alfragide
P-2720 Amadora

REPUBLIQUE TCHEQUE
DIC Czech Republic-NATO RTO
VTÚL a PVO Praha
Mladoboleslavská ul.
Praha 9, 197 06, Česká republika

ROYAUME-UNI
Dstl Knowledge Services
Kentigern House, Room 2246
65 Brown Street
Glasgow G2 8EX

TURQUIE
Millî Savunma Başkanliği (MSB)
ARGE Dairesi Başkanliği (MSB)
06650 Bakanliklar - Ankara

AGENCES DE VENTE

NASA Center for AeroSpace Information (CASI)
Parkway Center
7121 Standard Drive
Hanover, MD 21076-1320
Etats-Unis

The British Library Document Supply Centre
Boston Spa, Wetherby
West Yorkshire LS23 7BQ
Royaume-Uni

Canada Institute for Scientific and Technical Information (CISTI)
National Research Council
Acquisitions
Montreal Road, Building M-55
Ottawa K1A 0S2, Canada

Les demandes de documents RTO ou AGARD doivent comporter la dénomination "RTO" ou "AGARD" selon le cas, suivie du numéro de série (par exemple AGARD-AG-315). Des informations analogues, telles que le titre et la date de publication sont souhaitables. Des références bibliographiques complètes ainsi que des résumés des publications RTO et AGARD figurent dans les journaux suivants:

Scientific and Technical Aerospace Reports (STAR)
STAR peut être consulté en ligne au localisateur de ressources uniformes (URL) suivant:
http://www.sti.nasa.gov/Pubs/star/Star.html
STAR est édité par CASI dans le cadre du programme NASA d'information scientifique et technique (STI)
STI Program Office, MS 157A
NASA Langley Research Center
Hampton, Virginia 23681-0001
Etats-Unis

Government Reports Announcements & Index (GRA&I)
publié par le National Technical Information Service
Springfield
Virginia 2216
Etats-Unis
(accessible également en mode interactif dans la base de données bibliographiques en ligne du NTIS, et sur CD-ROM)

Imprimé par Groupe d'imprimerie St-Joseph inc.
(Membre de la Corporation St-Joseph)
1165, rue Kenaston, Ottawa (Ontario), Canada K1G 6S1

NORTH ATLANTIC TREATY ORGANISATION

RESEARCH AND TECHNOLOGY ORGANISATION

BP 25 • 7 RUE ANCELLE

F-92201 NEUILLY-SUR-SEINE CEDEX • FRANCE

Telefax 0(1)55.61.22.99 • E-mail mailbox@rta.nato.int

DISTRIBUTION OF UNCLASSIFIED RTO PUBLICATIONS

NATO's Research and Technology Organisation (RTO) holds limited quantities of some of its recent publications and those of the former AGARD (Advisory Group for Aerospace Research & Development of NATO), and these may be available for purchase in hard copy form. For more information, write or send a telefax to the address given above. **Please do not telephone**.

Further copies are sometimes available from the National Distribution Centres listed below. If you wish to receive all RTO publications, or just those relating to one or more specific RTO Panels, they may be willing to include you (or your organisation) in their distribution.

RTO and AGARD publications may be purchased from the Sales Agencies listed below, in photocopy or microfiche form. Original copies of some publications may be available from CASI.

NATIONAL DISTRIBUTION CENTRES

BELGIUM
Etat-Major de la Défense
Département d'Etat-Major Stratégie
ACOS-STRAT-STE – Coord. RTO
Quartier Reine Elisabeth
Rue d'Evère, B-1140 Bruxelles

CANADA
DRDKIM2
Knowledge Resources Librarian
Defence R&D Canada
Department of National Defence
305 Rideau Street, 9th Floor
Ottawa, Ontario K1A 0K2

CZECH REPUBLIC
DIC Czech Republic-NATO RTO
VTÚL a PVO Praha
Mladoboleslavská ul.
Praha 9, 197 06, Česká republika

DENMARK
Danish Defence Research Establishment
Ryvangs Allé 1, P.O. Box 2715
DK-2100 Copenhagen Ø

FRANCE
O.N.E.R.A. (ISP)
29 Avenue de la Division Leclerc
BP 72, 92322 Châtillon Cedex

GERMANY
Streitkräfteamt / Abteilung III
Fachinformationszentrum der Bundeswehr, (FIZBw)
Friedrich-Ebert-Allee 34
D-53113 Bonn

GREECE (Point of Contact)
Defence Industry & Research General Directorate
Research Directorate
Fakinos Base Camp
S.T.G. 1020
Holargos, Athens

HUNGARY
Department for Scientific Analysis
Institute of Military Technology
Ministry of Defence
H-1525 Budapest P O Box 26

ICELAND
Director of Aviation
c/o Flugrad
Reykjavik

ITALY
Centro di Documentazione Tecnico-Scientifica della Difesa
Via XX Settembre 123a
00187 Roma

LUXEMBOURG
See Belgium

NETHERLANDS
Royal Netherlands Military Academy Library
P.O. Box 90.002
4800 PA Breda

NORWAY
Norwegian Defence Research Establishment
Attn: Biblioteket
P.O. Box 25, NO-2007 Kjeller

POLAND
Armament Policy Department
218 Niepodleglosci Av.
00-911 Warsaw

PORTUGAL
Estado Maior da Força Aérea
SDFA - Centro de Documentação
Alfragide
P-2720 Amadora

SPAIN
INTA (RTO/AGARD Publications)
Carretera de Torrejón a Ajalvir, Pk.4
28850 Torrejón de Ardoz - Madrid

TURKEY
Millî Savunma Başkanliği (MSB)
ARGE Dairesi Başkanliği (MSB)
06650 Bakanliklar - Ankara

UNITED KINGDOM
Dstl Knowledge Services
Kentigern House, Room 2246
65 Brown Street
Glasgow G2 8EX

UNITED STATES
NASA Center for AeroSpace Information (CASI)
Parkway Center
7121 Standard Drive
Hanover, MD 21076-1320

SALES AGENCIES

NASA Center for AeroSpace Information (CASI)
Parkway Center
7121 Standard Drive
Hanover, MD 21076-1320
United States

The British Library Document Supply Centre
Boston Spa, Wetherby
West Yorkshire LS23 7BQ
United Kingdom

Canada Institute for Scientific and Technical Information (CISTI)
National Research Council
Acquisitions
Montreal Road, Building M-55
Ottawa K1A 0S2, Canada

Requests for RTO or AGARD documents should include the word 'RTO' or 'AGARD', as appropriate, followed by the serial number (for example AGARD-AG-315). Collateral information such as title and publication date is desirable. Full bibliographical references and abstracts of RTO and AGARD publications are given in the following journals:

Scientific and Technical Aerospace Reports (STAR)
STAR is available on-line at the following uniform resource locator:
http://www.sti.nasa.gov/Pubs/star/Star.html
STAR is published by CASI for the NASA Scientific and Technical Information (STI) Program
STI Program Office, MS 157A
NASA Langley Research Center
Hampton, Virginia 23681-0001
United States

Government Reports Announcements & Index (GRA&I)
published by the National Technical Information Service
Springfield
Virginia 22161
United States
(also available online in the NTIS Bibliographic Database or on CD-ROM)

ST JOSEPH OTTAWA/HULL

Printed by St. Joseph Print Group Inc.
(A St. Joseph Corporation Company)
1165 Kenaston Street, Ottawa, Ontario, Canada K1G 6S1

ISBN 92-837-0034-1